APPENDIX C
HYDROLOGIC SIMULATION PROGRAM - FORTRAN MODEL FOR ST. LUCIE BASIN

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DESCRIPTION OF THE ST. LUCIE BASIN

The St. Lucie River Basin (**Figure C-1**) is located on the southeastern coast of Florida, encompassing 780 square miles. The North and South Forks of the St. Lucie River flow into the St. Lucie River Estuary and through the southern portion of the Indian River Lagoon before discharging to the Atlantic Ocean. The estuary and southern lagoon together form a 30-square mile tidal influenced water body that supports a fragile macrophyte-based estuarine ecosystem.

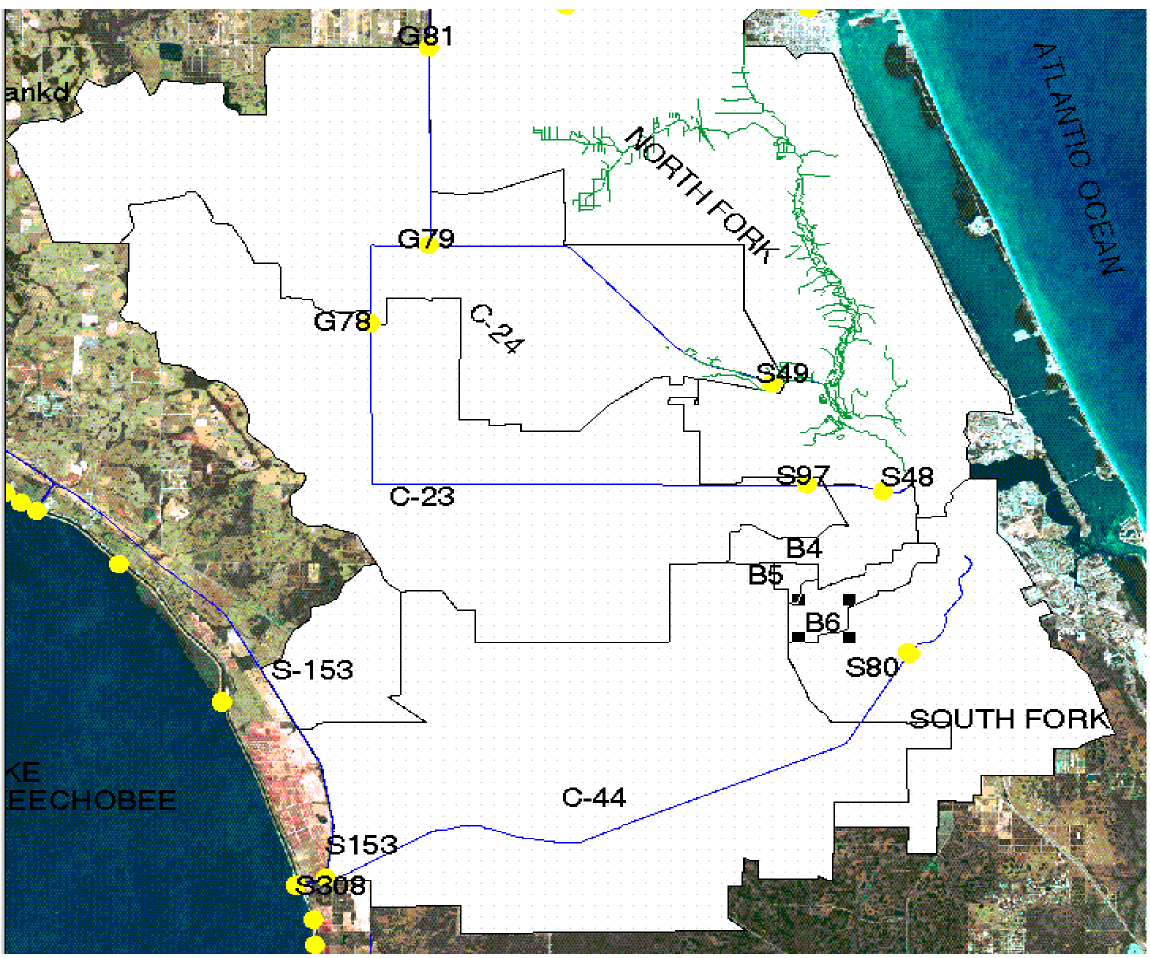

Figure C-1. Primary Drainage Basin in the St. Lucie Estuary Watershed

The watershed can be divided into the following drainage basins based on major drainage features:

- North Fork St. Lucie
- C-24 Canal Basin
- C-23 Canal Basin
- C-44 Canal Basin
- Basins 4, 5, and 6 of the Bessey and Dan Fork Creeks
- S-153 Basin
- Tidal St. Lucie Basin

The topography of the watershed rises gently from sea level on the east to approximately 30 feet National Geodetic Vertical Datum (NGVD) at the coastal ridge. West of the coastal ridge is very low fat land such as Allapattah Flats (elevation of 24 to 30 feet NGVD). Further west, the slope of the land becomes steeper to more than 50 feet NGVD. Areas of depression (wetlands, swamps etc.) and small ridges occur throughout the watershed.

Soils in the area range from low to high potential seepage rates. The geology of the watershed is dominated by the flatwood soil and soils of sloughs and freshwater marshes, both of which are poorly drained and generally flat.

The climate of the St. Lucie River and Estuary watershed is affected by the subtropical influences of the Atlantic Ocean and Lake Okeechobee. Annual mean temperatures is about 73 degree F and average annual rainfall is about 52 inches per year. A wet season occurs from mid-May through mid October, during which about 62 percent of the rainfall occurs. Tropical storms and hurricanes typically occur during wet season and contribute substantial amount of rainfall.

Various land use/land covers exist in the area. Agricultural land use is the dominant land cover in the watershed, with citrus groves and improved and unimproved pasture being most extensive. Scattered tracts of rangeland, scrub/brushland, and forested uplands occur throughout the area. Forested and nonforested wetlands make up a significant part of the watershed, but much of the historical wetland areas have been converted to agricultural use. Developed residential and commercial centers are concentrated in the eastern part of the area, near the St. Lucie River.

Since the early 1900s canals and water control structures were built to make the region more suitable for agricultural, industrial, and urban development. The original river basin was about 260 square miles but nearly tripled in size after the construction of numerous irrigation and drainage canals. Flood control releases from Lake Okeechobee can also be made through the canals and are often harmful to the estuary. These changes to the landscape and drainage have increased peak discharge rates and volumes during storm events, increased sediment and nutrient loads, and all but eliminated base flows to the estuary during dry periods.

OVERVIEW OF HYDROLOGIC AND HYDRAULIC MODELS

The South Florida Water Management District (SFWMD) and United States Army Corps of Engineers have jointly undertaken a feasibility study which will develop a regional watershed management plan that will improve the quality and temporal distribution of flows to the estuary and lagoon. Hydrologic and hydraulic models of the basin and its canal systems have been developed as part of the study. The Hydrologic Simulation Program FORTRAN (HSPF) Model was selected for simulating hydrology and the Full Equations (FEQ) Model was chosen for hydraulic routing for the extensive and largely managed canal system under tidal influence conditions and flood conditions where backwater and reversed flow would be a concern. The existing version of HSPF (version 11) was inadequate for simulating wetlands and high water table conditions found within the St. Lucie River Basin. The District contracted the firm of Aqua Terra Consultants to implement changes in the hydrology module of HSPF to allow an improved representation of wetlands conditions and dynamic water table variations common to the South Florida region. This modified version of HSPF will become HSPF 12.0 (Version 12). The following paragraphs described the standard versions of the HSPF, FEQ, and HSPF 12.0.

Hydrologic Simulation Program - FORTRAN

The Hydrologic Simulation Program – FORTRAN (HSPF) has been used since 1971 throughout the United States and abroad for all types of land uses. It simulates hydrologic processes including snow accumulation and melt for overland flow under various land use/land covers and water quality processes. Channel processes and reservoirs are also simulated. HSPF is a continuous simulation model. The time scale of simulation varies from 5 minutes to hourly, depending on the process. Statistical analysis of continuous output time series is used to produce data for economic analysis of alternate water management plans.

The hydrology and hydraulic input requirements of HSPF are precipitation, evaporation, temperature, soil properties, channel properties, land use, topography, supplemental irrigation for crops, etc. The output from the HSPF are time series of flow (e.g., surface runoff, interflow, base flow, deep seepage into deep groundwater system), stages (e.g., ground water tables, water levels in streams and rivers), etc. All input and output time series are stored in HECDSS files for FEQ model or other result presentations.

The components of watershed water quality models of the HSPF are nonpoint source loading simulations and in stream simulations. Nonpoint source loading simulation includes runoff quantity (surface and subsurface), sediment erosion/solids loading, runoff quality, atmospheric deposition, and input needed by in stream simulation. In stream simulation includes hydraulics, sediment transport, sediment-contaminant interactions, water quality constituents and processes, point source accommodation, reservoir simulation, and benthal processes and impacts.

Full Equations

Full Equations (FEQ) is a one-dimensional full equation hydrodynamic flow routing model. The model computes flow and elevation in channel networks for evaluations including the effect of adding, changing, or abandoning a reservoir and the effect of operation policy for gates or pumps. This model has been applied in Illinois to various types of projects including transportation, county level, and geological survey projects. In the St. Lucie River watershed, FEQ can be used to simulate hydraulics in primary canal and transfers between primary and secondary/tertiary canals. Secondary/ tertiary canals are represented as level pool reservoirs. Primary canal are connected to level pool reservoirs by culverts and pumps. Input includes runoff from HSPF (PERLND Module) and irrigation withdrawals. Output is in the form of time series of flow and stage in primary canals and is stored in HECDSS files.

OVERVIEW HSPF ENHANCEMENTS

The following assumptions were used in the standard version of the PWATER section of HSPF (version 11 or earlier):

- No exact storage locations exist for surface detention, interflow, upper/ lower zone and ground water storage.
- Deep or inactive ground water is not represented.
- The active ground water storage does not interact with the unsaturated zone.
- Both lower and upper zone storage are not affected by the active ground water.
- No percolation flows from the lower zone to active ground water.
- No limited capacity is associated with the interflow storage.
- Surface runoff is driven by the ground surface slope and no evaporation occurs from the surface detention storage.

Many of these assumptions are not valid in South Florida. In the South Florida environment the ground water is very close to the ground surface. The saturated zone interacts with, and even takes over, the unsaturated zone. In many areas the ground water reaches the surface and submerges the land for days or months. The land is so flat that the surface runoff is not driven by differences in ground elevation. Surface water impoundment is subject to evaporation.

All these invalid assumptions have been enhanced to meet South Florida hydrologic conditions, except the channel/reservoir routing (RCHRES), which is not valid under tidal and backwater conditions. The unsteady flow hydraulic model such as UNET and FEQ can be used in conjunction with the HSPF to route runoff through channel network system that are subject to tidal, backwater, and reserved flow conditions under extremely wet conditions. Due to considerations of data requirements (such as detail channel cross-sections, field operation data, etc.), computer processor unit storage requirements, and the intensive computer time (time step down to seconds), the linkage of HSPF and hydraulic model such as FEQ or UNET will be used when the basin runoff is subject to backwater or tidal flow conditions.

HSPF MODEL OF ST. LUCIE BASIN

Segmentation

The St. Lucie Basin is divided into six primary drainage basins: C-24, C-23, C-44, North Fork, and South Fork Tidal, and four minor basins (Basins 4,5, and 6, and the S-153). These primary drainage basins are further divided into several secondary subbasins. The basin was also divided into eleven precipitation segments using Thiessen polygons centered on rain gages shown in **Figure C-2**. However, due to missing data, concerns of computer storage capacity (31 years of hourly input and output for six land use types and hourly time step), and the available project time line, a simplified approach using average rainfall for each basin was applied and will be presented in detail later.

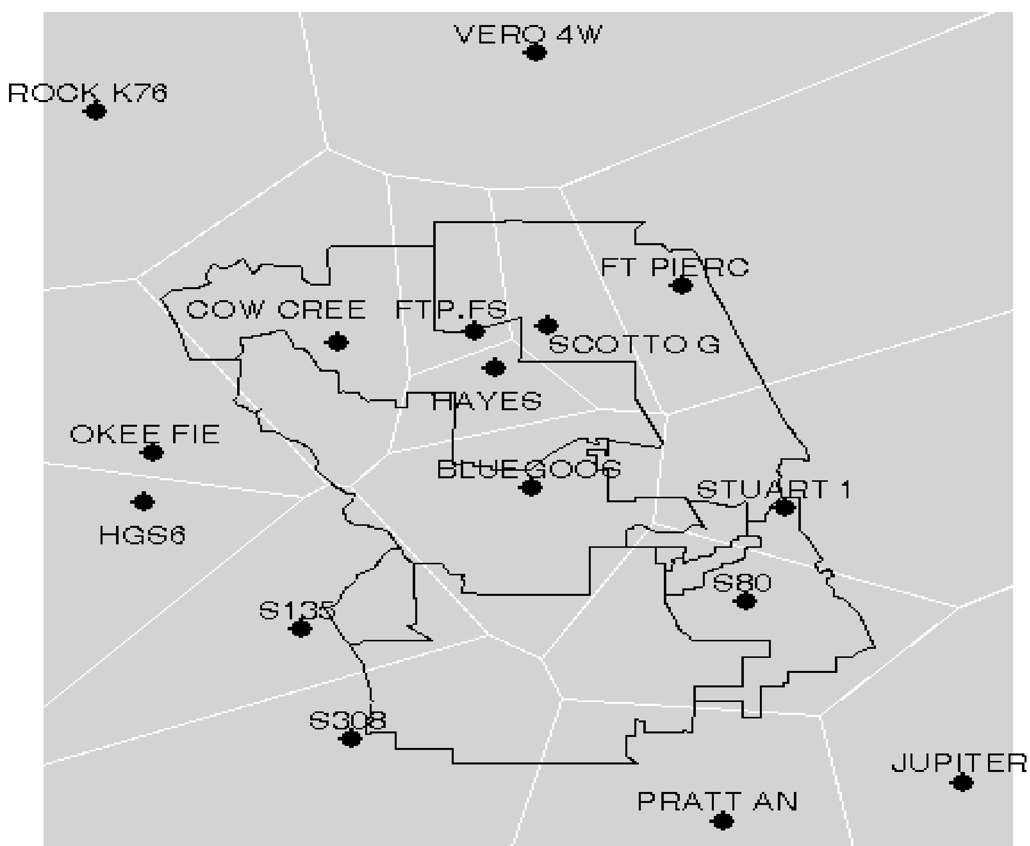

Figure C-2. Thiessen Map of the St. Lucie Estuary Watershed.

Land Use

The subbasin was further segmented by land use, which is one of the most important factors determining hydrologic response. Different treatment and/or characteristics of the soil are reflected in different hydrologic parameters. The 1988 land use conditions from the SFWMD Land Use and Land Cover Geographic Information System (GIS) database were updated to 1994 land use determined by the Coastal Environmental, Inc., under District's contract (Coastal Environmental, Inc., 1994). The following classifications were aggregated into five general categories for HSPF simulation:

- **Urban**: residential, institutional, commercial, industrial, transportation, open, other
- **Groves**: groves, sugarcane, truck farms, rice, ornamental, nurseries, tropical fruits, feedlot
- **Pasture**: improved/unimproved pasture, barren, rangeland
- **Forest**: forest
- **Wetland**: forested and nonforested wetlands

The Urban category is further divided into 60 percent pervious and 40 percent impervious. The impervious urban land is simulated using the IMPLND module of HSPF, while the pervious urban category is simulated using the PERLND module. A complete set of one IMPLND and five PERLNDs is used for each of the eleven precipitation segments. However, the precipitation segment was reduced into one segment for each basin to reduce computer storage requirement. **Table C-1** presents the land use by secondary subbasins for each major canal basin.

Table C-1. Land Use by Secondary Subbasin (unit in acres)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
C-23							
1	13	19	5	185	35	10	269
2	48	72	790	840	66	153	1,970
3	167	251	0	0	0	2	420
4	32	47	0	0	0	778	857
5	318	478	0	47	6	191	1,040
6	168	251	0	0	69	176	665
7	121	181	0	0	112	664	1,079
8	48	72	657	9	129	69	985
9	0	0	1,075	25	0	16	1,116
10	9	13	2,728	39	0	322	3,111
11	0	0	3,275	0	0	108	3,384
12	0	0	3,007	0	0	40	3,047
15	0	0	0	4,626	40	895	5,562
16	0	0	0	676	0	123	800

Table C-1. Land Use by Secondary Subbasin (unit in acres) (Continued)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
17	0	0	0	5,639	45	1,504	7,188
21	0	0	0	1,497	0	173	1,670
22	49	73	120	410	133	16	800
23	0	0	1,309	1,970	2	626	3,906
24	4	6	975	4	0	282	1,270
25	7	10	608	299	0	519	1,442
26	0	0	138	500	0	459	1,097
27	10	15	65	5,746	565	1,017	7,419
28	6	8	225	1,500	423	214	2,376
29	10	15	53	1,241	334	17	2,190
30	0	1	528	292	0	137	959
31	1	1	579	242	30	788	1,641
32	0	0	546	186	33	21	787
33	0	0	0	293	78	70	440
34	0	0	0	474	115	145	734
35	60	90	1,627	628	79	261	2,745
36	0	0	34	255	120	147	556
37	0	0	75	488	533	429	1,526
38	0	0	0	341	0	206	547
39	38	57	138	828	99	222	1,382
40	3	4	1,022	8,429	1,604	1,521	12,582
41	0	0	618	0	0	42	660
42	0	0	1,511	0	0	16	1,526
43	29	43	2,160	233	46	49	2,560
44	0	0	288	0	0	0	288
45	0	0	414	0	0	0	414
46	0	0	291	0	0	0	291
47	0	0	181	0	0	0	181
48	0	0	350	0	0	0	350
49	0	0	1,161	0	0	0	1,161
50	0	0	1,009	0	1	4	1,015
51	0	0	1,265	5	2	379	1,650
52	0	0	4,149	50	55	45	4,298
53	73	109	789	8,216	633	7,099	16,919
C8	40	60	9	0	0	0	345
C9	6	8	0	760	0	888	1,662
C10	0	0	1	155	0	233	389
K5	15	22	298	0	0	0	335
C-23 Total	**1,273**	**1,909**	**34,076**	**47,127**	**5,387**	**21,078**	**111,606**
South Fork							
1	313	469	0	0	3	1	786
2	398	597	8	15	162	25	1,206
3	233	349	13	0	203	55	854
4	738	1,108	91	76	476	844	3,332
5	68	101	0	0	26	121	316
6	156	234	50	103	22	692	1,256
7	23	35	0	0	0	3	61

Table C-1. Land Use by Secondary Subbasin (unit in acres) (Continued)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
8	13	19	0	0	0	0	32
9	34	50	0	0	12	2	98
10	388	582	696	157	271	1,431	3,525
11	701	1,051	3,063	11,998	1,548	8,014	26,375
12	404	606	209	486	599	281	2,585
14	170	254	829	594	388	117	2,352
15	34	52	357	765	135	13	1,357
16	0	0	478	32	136	0	646
x17	256	385	615	480	568	453	2,757
South Fork Total	**3,928**	**5,892**	**6,409**	**14,706**	**4,548**	**12,053**	**47,537**
Basin 4							
1	427	641	0	45	73	109	1,296
2	195	0	0	0	9	6	503
3	122	183	0	0	77	98	479
4	160	240	59	81	92	180	812
5	174	261	0	34	52	28	550
6	44	66	0	18	14	11	153
7	66	100	0	5	261	0	431
8	18	27	96	269	90	1	501
9	3	4	0	314	260	1	581
10	1	2	0	81	307	3	395
11	0	0	2	518	236	119	874
12	0	0	21	27	9	0	56
13	50	75	25	0	36	1	188
14	5	8	11	4	21	0	48
15	31	46	0	0	44	0	121
16	6	9	0	2	21	0	38
17	14	21	0	0	68	0	103
18	4	6	0	22	94	0	126
19	7	11	0	18	24	1	61
20	9	13	0	64	39	3	128
21	0	0	0	21	9	1	30
22	17	25	0	50	23	0	115
23	74	111	0	23	53	317	577
24	11	17	5	85	82	6	207
25	2	3	0	6	176	393	580
Basin 4 Total	**1,441**	**1,870**	**220**	**1,687**	**2,165**	**1,278**	**8,953**
Basin 5							
1	27	40	9	9	57	1	144
2	22	33	5	4	4	0	68
3	157	236	6	29	190	129	747
Basin 5 Total	**206**	**309**	**21**	**42**	**251**	**131**	**959**
Basin 6							
1	100	150	21	2	170	2	446
2	127	190	3	172	42	98	632
3	21	31	0	127	1	1	180
4	24	35	0	32	39	5	135

Table C-1. Land Use by Secondary Subbasin (unit in acres) (Continued)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
5	4	5	0	61	4	0	74
6	16	24	0	0	47	0	87
7	7	11	32	0	13	0	62
8	28	42	39	26	20	0	155
9	12	17	0	0	31	0	60
10	39	58	44	44	28	0	212
11	120	181	24	145	267	112	849
12	23	35	10	30	25	0	123
13	50	75	0	32	0	0	157
14	79	118	10	11	83	0	301
15	186	278	0	120	115	11	710
16	29	43	0	1	190	394	658
Basin 6 Total	**863**	**1,295**	**183**	**801**	**1,075**	**624**	**4,840**
North Fork							
A1	1,399	2,098	0	0	368	2,355	6,220
A2	3,125	4,688	0	0	319	337	8,469
B1	2,015	3,022	1	10	987	3,277	9,312
B2	0	0	0	0	44	0	45
B3	5	8	15	0	26	0	55
C1	1,321	1,981	0	4	42	126	3,474
C2	891	1,336	0	0	1	282	2,509
C3	801	1,201	0	0	0	153	2,155
D1	417	626	9	3	403	278	1,736
D2	387	580	0	0	319	580	1,866
D3	113	170	0	0	7	14	304
D4	8	12	0	0	1	0	20
E1	82	123	144	7	175	228	759
E2	381	571	246	53	303	208	1,761
F1	2,653	3,980	0	0	215	614	7,462
F2	453	680	0	767	1,441	216	3,558
G1	488	733	76	433	710	545	2,984
G2	1,056	1,584	138	357	1,482	473	5,090
H1	186	280	55	2	130	92	744
H2	134	201	64	114	92	54	660
I	208	313	44	558	314	344	1,781
J	185	278	291	329	230	459	1,771
K	170	255	0	0	46	43	513
L	176	265	0	13	105	6	565
M	4	6	0	37	10	67	124
N	17	26	12	30	18	78	183
O	25	37	22	6	0	50	139
P	25	38	105	10	63	174	414
Q	38	56	94	21	29	100	338
R	14	21	408	144	15	149	752
S	347	520	1,645	655	1,172	392	4,730
T	26	38	237	67	162	18	548
U	85	127	2,074	411	462	1,336	4,494

Table C-1. Land Use by Secondary Subbasin (unit in acres) (Continued)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
V	21	31	6,724	68	13	129	6,984
W1	53	80	580	353	168	1	1,235
W2	60	90	475	489	104	17	1,236
W3	82	123	2,738	128	118	44	3,232
W4	8	12	1,083	11	13	0	1,127
W5	1	1	607	8	0	29	645
W6	4	6	2,059	22	3	5	2,098
W7	0	0	1,836	143	0	109	2,088
W8	1	2	2,255	9	0	148	2,416
W9	0	0	2,086	6	8	0	2,101
X1	254	382	56	0	44	0	736
X2	201	301	0	0	40	0	542
X3	98	146	103	5	55	20	427
X4	197	296	175	12	33	2	715
X5	168	252	226	98	199	9	952
X6	148	222	340	28	255	37	1,031
X7	99	148	193	37	156	5	639
X8	41	62	0	0	0	0	103
X9	245	368	103	0	145	25	887
North Fork Total	**18,916**	**28,373**	**27,317**	**5,448**	**11,047**	**13,630**	**104,731**
			C-24				
A	372	559	0	0	42	100	1,073
B	120	180	0	0	1	38	339
C1	47	70	908	917	71	545	2,559
C2	2	3	199	654	160	748	1,767
C3	15	22	1,483	3	48	132	1,703
C4	2	3	960	29	1	21	1,015
C5	10	15	294	530	14	92	956
C6	0	0	152	123	2	9	286
C7	20	30	9	457	104	230	849
D	340	510	348	0	1,904	80	3,183
E	0	0	294	2	0	24	320
F	2	3	366	0	0	11	381
G	0	0	610	0	26	333	968
H1	3	5	199	2,650	569	354	3,780
H2	0	0	0	388	207	22	617
I	0	0	259	12	0	20	291
J	0	0	82	191	2	104	379
K1	5	8	1,287	144	33	6	1,484
K2	0	0	6	309	25	0	340
K3	26	38	316	424	130	78	1,011
K4	0	0	7	353	0	23	383
K6	0	0	630	10	0	0	640
K7	1	1	9	429	3	50	494
K8	0	0	96	3	0	0	99
L	115	172	1,948	1,935	184	159	4,512
M	0	0	236	0	0	64	299

Table C-1. Land Use by Secondary Subbasin (unit in acres) (Continued)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
N	0	0	310	12	0	0	322
O	0	0	36	1,302	190	106	1,633
P1	0	0	978	1,095	96	43	2,212
P2	0	0	320	0	0	0	320
P3	0	0	8	3,315	3	532	3,858
P4	0	0	955	5	0	4	964
P5	0	0	290	13	0	33	336
P6	0	0	1,025	31	87	146	1,289
P7	0	0	0	614	0	26	641
P8	0	0	641	492	0	741	1,874
P9	0	0	0	661	9	178	848
P10	0	0	609	5	1	34	649
Q	0	0	15	1,253	58	33	1,359
R	0	0	933	4	19	1	958
S	0	0	826	0	6	11	842
T	0	0	268	0	3	4	275
U	89	133	2,126	23,302	2,969	13,455	42,072
V	0	0	282	152	3	0	437
C-24 Total	**1,169**	**1,753**	**20,318**	**41,818**	**6,968**	**18,590**	**90,617**
S-153							
S-153	447	671	2,069	4,129	1,428	4,175	12,920
S-153 Total	**447**	**671**	**2,069**	**4,129**	**1,428**	**4,175**	**12,920**
C-44							
1	0	0	198	1,584	156	46	1,984
2	0	0	12	1,976	170	1,852	4,010
3	80	120	748	1,004	265	1,248	3,464
4	72	107	3,993	2,628	397	2,085	9,281
5	17	25	705	814	23	16	1,600
6	0	0	2,955	0	194	12	3,161
7	0	0	1,586	1,062	95	327	3,071
8	38	57	215	1,512	0	319	2,141
9	0	0	1,886	8	76	0	1,971
10	16	23	656	1,210	393	807	3,104
11	1	2	819	0	60	0	881
12	3	4	1,718	385	0	1,484	3,594
13	0	0	7,808	248	140	726	8,921
14	231	346	6,866	4,875	1,112	998	14,428
15	34	51	0	9	245	2	341
16	303	454	933	918	744	272	3,625
17	12	18	4,781	478	91	3,290	8,670
18	6	9	859	4	24	0	902
19	2	4	3,254	0	279	5	3,545
20	0	0	2,020	0	499	0	2,520
21	74	111	476	84	30	167	940
22	0	0	1,223	196	0	4	1,423
23	100	150	931	0	216	445	1,841
24	267	401	1,828	186	167	2,007	4,856

Table C-1. Land Use by Secondary Subbasin (unit in acres) (Continued)

Subbasin	Urban Impervious	Urban Pervious	Groves	Pasture	Forest	Wetland	Total
25	2	3	0	0	0	1,609	1,614
26	16	24	43	216	0	1,384	1,681
27	13	19	23	22	24	742	842
28	0	0	11	0	81	117	210
29	28	42	1,038	0	390	0	1,498
30	395	592	405	51	439	7,377	9,259
31	17	26	881	5,905	1,180	2,708	10,717
C-44 Total	**1,724**	**2,587**	**48,873**	**25,372**	**7,490**	**30,049**	**116,095**
Grand Total	29,968	44,659	139,486	141,131	40,359	101,607	498,258

Rainfall

Rainfall data was extracted from SFWMD's DBHYDRO database. Data from 11 daily and 6 hourly rainfall stations were used (**Table C-2**). Missing data were filled from adjacent stations (Table C-2). Three of the hourly stations within and near the basin have periods of record from 1965 to 1995. These stations were used to desegregate the daily data for each basin to produce hourly data for use in the HSPF simulations, covering the period from 1965 to 1995.

Table C-2. Summary of Rainfall Data for St. Lucie Basin Simulations

Station Identification Number	Station Name	Period of Record
Daily Rainfall Stations		
NOAA -6032	Fort Pierce	1962-1995
MRF-39	Scotto Groves	1962-1995
MRF-37	Fort Pierce Field Station	1971-1995
MRF-148	Cow Creek Ranch	1971-1995
MRF-40	Hayes Property	1971-1995
MRF-241	Bluegoose	1979-1995
NOAA-6082	Stuart 1N	1957-1995
MRF-7035	S80(NOAA-7859)	1957-1995
MRF-54	Pratt and Whitney	1957-1995
MRF-7037	S308(NOAA-7293)	1957-1995
MRF-150	S-153	1972-1995
Hourly Stations		
MRF-40	Hayes Property	1971-1995
MRF-148	Cow Creek Ranch	1970-1995
MRF-241	Bluegoose	1979-1995
MRF-7035	S80(NOAA-7859)	1965-1994
MRF7037	S308(NOAA-7293)	1965-1994
NOAA-9219	Vero Beach 4W	1965-1995

Accumulated rainfall was determined by applying a weighing factors to the data from each station. **Table C-3** presents rainfall stations and weighing factors used for each basin in the St. Lucie Basin.

Table C-3. Rainfall Stations and Weighing Factors Used for Each Basin

Basin	Rainfall Station	Weighing Factor	Period of Record
C-23	MRF148 MRF40 MRF44 MRF150 MRF7035	0.30 0.25 0.10 0.15 0.20	1972-1978
	MRF148 MRF241 MRF44 MRF150 MRF7035	0.30 0.40 0.10 0.10 0.10	1979-1995
C-24	MRF148 MRF40 MRF37	0.3333 0.3333 0.3333	1971-1978
	MRF148 MRF40 MRF37 MRF241	0.25 0.25 0.25 0.25	1979-1995
C-44	MRF7035 MRF7037 MRF54	0.40 0.40 0.20	1957-1971
	MRF150 MRF7035 MRF7037 MRF54	0.15 0.35 0.35 0.15	1972-1995
North Fork	MRF6032 MRF39 MRF37 MRF6082	0.40 0.25 0.15 0.20	1965-1995
Ten Mile Creek	MRF6032 MRF39	0.50 0.50	1965-1995
S-153	MRF7037	1.00	1965-1970
	MRF150	1.00	1971-1995
South Fork Tidal	MRF6082 MRF7035 MRF54	0.20 0.70 0.10	1965-1995

Evaporation

Daily evaporation data are available at three locations within or near the watershed: Fort Pierce Experimental Station, Belle Glade Experimental Station, and Hurricane Gate Structure 6. The potential evapotranspiration record at Fort Pierce Station is the primarily data used in the model. Missing data in this station were filled using the other two stations. The model uses pan coefficient to derive an estimate of potential evapotranspiration. Actual (simulated) evapotranspiration is based on three general factors: the model algorithms, the evapotranspiration parameters, and the input potential evapotranspiration. The pan coefficients were determined by applying a model calibration process based on the chemicals, runoff, and erosion from agricultural management system with water table (CREAMS-WT) model to the C-23 and C-24 Basins. The pan coefficients chosen were 0.60 for the C-24 Basin and 0.64 for the rest of the watershed.

Soils, Slopes, and Elevation

The District's GIS database contains land use/cover, soil types, topography, and hydrography. The soil properties database contains hydrologic soil group, permeability, porosity (maximum/minimum available water capacity), and erosion factor. The data are generally available for two depth horizons (0 to 20 inches and 20 to about 60 inches). However, some secondary basins do not have soil data due to owners' access restriction to their properties. The available data were used to estimate the range and the variability of porosities, infiltration rates, and soil storage parameters in PERLND module.

Land slopes are not generally used in the HSPF12.0. However, average elevations for each segment were estimated from the United States Geological Survey (USGS) 7.5-minute quad maps. For Ten Mile Creek Basin, the data with topography data of early 1980 was used. Portions of eastern Martin County were available from the District's GIS database.

Supplemental Irrigation

One of the major environmental concerns in both the St. Lucie Estuary and Indian River Lagoon is the timing and distribution of freshwater inputs that results from postproject conditions. The present freshwater flow pattern has been characterized as the follows:

- Low flows are exaggerated during the dry season months.
- Reduction or lack of flush from spring rainfall is caused by irrigation for agricultural activities.
- An excess quantity of fresh water is received during the wet season for crop and residential flood protection.
- Drainage capacity is increased compared to preproject conditions.

The canal system primarily serves as a source of agricultural irrigation water and a means to control water table levels to maximize crop production and reduce flood damages. During the wet season, flows to the estuary often increase abruptly and result in much greater volumes of freshwater discharge to the estuary compared to predevelopment conditions. Conversely, during the dry season, fresh water is in short supply and the canal system is controlled to retain and reuse fresh water for irrigation to the maximum extent possible. These activities greatly reduce dry season base flows that normally would enter the estuary under preproject condition.

Site-specific data on irrigation application amounts, acreage, and timing were scarce. The water use permits did not provide sufficient information to be useful in the model simulation. The amounts of irrigation withdrawn from surface water to mix with ground water sources are not easily estimated.

The irrigation method and the acreage irrigated, in general, are available from the *Indian River Lagoon Agricultural Land-Use Inventory and Discharge Study* prepared by the United States Department of Agriculture's Soil Conservation Service in December 1993 (SCS, 1993). The information was compiled by using the Agricultural Field-Scale Irrigation Requirements Simulation (AFSIRS) developed by Smajstrla, (1990). The AFSIRS was used to develop 31 years of daily irrigation demands and irrigation supply for the North Fork and C-44 basins. The results were compared (a calibration process) to the supplemental irrigation derived from the model calibrated results for C-23 and C-24 Basins (see below).

The amounts of irrigation used by the citrus growers are based on the observed daily water levels, daily flow at water control structures, and channel cross-sections. The daily withdrawal was estimated by the daily stage difference and the stage-area-volume relationship derived from the channel cross-section. This volume of water was then divided by the total irrigated area to come up with irrigation amount in inches per day for 31 years. This amount was than increased by 40 percent (SFWMD, 1998) to cover the additional water withdrawn from deep ground water sources. A time series of total daily irrigation withdrawal (both from surface and deep ground water sources) for 31 years was developed, and applied in the HSPF model calibration simulations. These time series were adjusted for additional precipitation for the citrus groves within the basin. This data set was further adjusted based on the calibration of discharge through structure, and water level agreements between computed and observed data at the structure.

HSPF USER CONTROL INPUT FILES

A single user's control input file that simulates the runoff from land area within the St. Lucie River and Estuary watershed was set up for each basin. The user's control input file breaks down the basin primarily by precipitation segment, rather than by secondary basin boundaries. In each of the eleven precipitation segments, there are five land use categories represented by five PERLND operations plus one IMPLND operation, which models the impervious fraction of the urban category. These operation produce per acre water yield (runoff) for each land segment. The outflows are multiplied by the corresponding acreage in the SECHEMATIC block and accumulated by the COPY operations to give the total runoff for each basin. The times series of runoff, hourly rainfall, daily evaporation, irrigation supply, and withdraw are stored in the HECDSS data file.

Table C-4 presents a list of land use-specific hydrology parameters and calibration values used in the HSPF model developed for the St. Lucie River and Estuary watershed. INFILT is the infiltration, CEPSC is the interception storage capacity, UZSN is the upper zone nominal storage, LZSN is the lower zone nominal storage, and LZETP is the lower zone evapotranspiration.

Table C-4. Land Use-Specific Hydrology Parameters Used in HSPF for the St. Lucie Watershed

Parameter	Urban/Pasture	Groves	Forests	Wetlands
(INFILT (inches per hour)	0.08	0.10	0.12	0.04
CEPSC (inches)	0.10	0.14	0.10	0.10
UZSN (inches)	0.30	0.60	0.60	0.20
LZSN (inches)	3.00	3.00	3.00	2.50
LZETP	0.30	0.45	0.50	0.45

Table C-5 presents a list of wetland hydrology parameters and calibration values used in the HSPF model developed for the St. Lucie River and Estuary watershed. Wetlands are assumed to lie at a lower mean elevation (MELEV), resulting in a lower zone nominal storage, and the interflow parameter (INTFW) is set to zero and the interflow recession constant (IRC) is set equal to base flow recession. The flag value for selecting the algorithm for computing surface runoff from the wetland category is RTOPFG. If RTOPFG is 1, routing of overland flow is done in the same way as in the predecessor models HSPX, ARM, and NPS. A value of 2 results in use of a simple power function method. If a value of 3 is entered, the program uses a table in the function tables (FTABLES) block to determine surface outflow as a function of surface storage. The parameter STABNO gives the identification number to be found in the FTABLES block of the user's control input file. If STABNO is 1 for the wetlands, Function Table 1 is used for runoff from the wetland. The recession constant is SRRC and the recession exponent is SREXP. These parameters are used to relate surface runoff to surface storage

Table C-5. Wetland Hydrology Parameters

Parameter	Urban/Pasture	Groves	Forests	Wetlands
RTOPFG	2	2	2	3
INTFW	1.00	1.00	1.00	0.00
IRC (/day)	0.90	0.95	0.90	0.99
MELEV	27.00	27.00	27.00	24.70
STABNO	-	-	-	1
SRRC (/hour)	0.90	0.90	0.90	-
SREXP	1.00	1.00	1.00	-
IFWSC (inches)	1.00	1.00	1.00	1.00

RCHRES MODULE

The channel/reservoir routing section (RCHRES) module is used if daily flow daily stage data and channel cross-sections were available. These data help to better define the storage available in the existing basin. If no measured historical data is available for model calibration, the RCHRES module is not used and the black box approach is used for that basin. The RCHRES module was used in the C-23 and C-24 Basins when data was available.

Numerous pumps and culverts connect the project canal with the secondary drainage ditches in the land adjacent to the canal. Citrus areas represent the most intensive drainage network because of their flood protection and water supply needs. Pumps are most common for the citrus lands and in general the drainage capacity was designed to remove 2 inches per day of runoff from their lands. Due to a lack of field data, assumptions were made for the secondary and tertiary canals. These assumptions are as follows:

- Secondary drainage canal for a typical citrus land
  - Cross-section - 35 feet bottom width at 18.0 feet NGVD
  - Side slope - 1 vertical on 2 horizontal
  - Total channel length per square mile area - 3 miles
  - Lowest bottom elevation - 14 feet NGVD
- Tertiary canal for a typical citrus land
  - Cross-section - 10 feet bottom width at 20.0 feet NGVD
  - Side slope - 1 vertical on 2 horizontal
  - Total channel length per square mile area -10 miles
- Secondary canal for non-grove lands
  - Cross-section - 20 feet bottom width at 19 feet NGVD
  - Side slope - 1 vertical on 2 horizontal
  - The lowest bottom elevation -14.0 feet NGVD
  - Total channel length per square mile area - 1 mile
- The tertiary canal network for noncitrus lands
  - Cross-section - 5 feet bottom width with elevation at 21 feet NGVD
  - Side slope - 1 vertical on 5 horizontal with depth
  - Total channel length per square mile area - 2 miles

A function table was then developed for both citrus and nongrove lands. The flow rates were adjusted during a calibration process based on a simulation of 31 plus years of daily data at the S-49 and S-97 structures.

Basins such as C-23 and C-24 were divided into three RCHRES sections. All citrus PERLND water are discharged into an RCHRES with an function table developed for that land use. Another RCHRES is used for nongrove lands. Water from both citrus and nongrove RCHRES were routed through the most downstream RCHRES, which is the project canal, before discharging into the estuary. The function table for the project canal was developed based on the most recent surveyed cross-sectional data available for the C-23 and C-24 Canals. Additional RCHRES can be incorporated into the model when additional secondary channel data become available.

CALIBRATION AND MODEL RESULTS

Calibration was performed on the C-24 Basin for the years from 1980 to 1992 by Aqua Terra Consultants, Inc., and Kraeger Associates in 1997. The simulated outflow was compared directly with the observed flow values. Several factors were discussed and were considered as problematic. These factors were further investigated and improved by the SFWMD staff during 1998. The SFWMD's continuing efforts are described in the following paragraphs.

Problem 1: Irrigation Application Data Not Available

The irrigation application amounts, timing, and sources are not available. A method of estimating the irrigation applied to groves was developed and relies on several assumptions regarding irrigation method, and irrigation and rainfall efficiency in meeting the demand. This approach, as presented in the 1997 report (Aqua Terra Consultants, Inc., and Kraeger Associates, 1977) was not considered satisfactory. For this reason, irrigation withdrawal from project canals was estimated using daily stage, flow, and channel cross-section data adjusted by an 40 percent (see the **Supplemental Irrigation** section on page 14). This 40 percent was included to represent water from deep ground water.

Problem 2: Unreliable Flow Data

The discharge rating curves for the S-49 structure used in the calibration simulations were updated using 12 flow measurements. The missing data or the data that had not been processed were recomputed by the SFWMD. However, the quality of flow data for the S-49 and S-97 structures is considered fair. **Tables C-6** and **C-7** present the monthly runoff coefficients based on the ratio of observed runoff and rainfall over the C-23 and C-24 Basins. The runoff coefficients that exceed 50 percent are not considered reliable. **Tables C-6** and **C-7** indicate that over 20 percent of the monthly data is not considered reliable. However, this is the best available data and nothing further can be done to improve its quality.

Table C-6. Monthly Runoff Coefficients for C-24 Basin Based on Observed Runoff Rainfall Ratio

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1965	0.00	9.03	4.04	0.00	0.00	0.00	7.68	1.95	15.38	18.22	28.11	1.87	86.27
1966	36.55	41.01	31.48	2.23	14.59	22.87	36.69	54.18	15.40	74.61	0.00	4.59	334.20
1967	0.00	7.57	0.00	0.00	0.00	12.40	13.25	1.07	38.50	22.79	11.58	0.00	107.16
1968	0.00	0.00	0.00	0.95	28.40	68.07	23.66	3.36	10.85	24.81	18.47	0.00	178.57
1969	75.72	25.20	41.49	81.00	16.91	23.56	15.40	90.98	65.64	52.05	93.48	94.29	675.71
1970	202.76	102.91	49.00	428.92	0.08	9.63	20.11	28.53	23.58	49.90	37.81	0.00	953.22
1971	0.00	4.55	48.85	0.00	0.15	9.32	36.40	31.06	58.97	42.17	101.07	9.89	342.42
1972	15.45	20.42	15.59	34.25	22.14	36.25	13.61	14.11	23.73	7.44	11.66	47.27	261.92
1973	25.51	39.39	17.23	19.96	6.06	23.00	26.05	35.37	51.51	62.66	870.40	10.58	1,187.73
1974	0.00	0.00	0.00	0.00	0.00	14.16	54.60	77.05	27.09	45.09	15.22	18.73	251.93
1975	39.14	0.00	0.00	0.00	12.79	18.90	29.92	30.26	28.39	53.06	30.31	24.97	267.74
1976	18.76	4.27	58.63	19.59	22.03	59.93	35.42	18.68	25.45	52.18	3.13	19.98	338.06
1977	18.87	16.54	44.46	0.00	0.00	1.46	1.63	16.81	36.56	8.18	20.05	46.69	211.26
1978	35.73	26.24	32.48	4.15	6.26	14.06	19.34	34.64	14.13	22.46	14.52	18.24	242.24
1979	68.94	274.50	3.43	0.00	34.80	19.14	15.64	16.76	57.77	111.75	53.90	31.68	688.32
1980	8.64	22.15	8.25	24.86	5.72	5.29	7.25	4.79	29.88	0.00	0.80	2.20	119.82
1981	0.00	0.00	0.00	0.00	0.00	0.00	4.18	20.06	46.74	11.13	0.00	0.00	82.11
1982	0.00	4.91	30.32	49.07	42.67	78.28	77.81	62.27	61.20	69.76	34.85	28.90	540.04
1983	8.90	74.21	93.26	39.67	0.00	18.01	7.04	27.41	38.81	75.91	113.01	20.98	517.21
1984	231.50	24.42	23.19	10.32	7.92	9.98	36.82	34.51	34.22	78.61	34.14	186.73	712.35
1985	10.60	0.00	12.49	19.40	0.00	1.64	39.45	48.70	62.00	82.65	12.82	0.00	289.76
1986	12.79	0.00	6.32	0.00	0.00	24.40	39.81	70.62	31.37	18.75	47.79	4.61	256.46
1987	52.66	8.54	21.01	77.70	0.00	0.00	28.16	18.64	11.01	32.81	76.57	11.08	338.17
1988	5.50	30.47	17.65	0.00	15.26	7.64	22.24	35.44	35.19	0.00	0.00	0.00	169.39
1989	0.00	0.00	7.92	1.76	2.64	0.00	20.76	42.84	42.37	40.84	5.70	15.86	180.70
1990	72.87	18.28	19.44	0.00	0.00	8.57	36.48	35.76	46.04	150.42	23.97	0.00	411.82
1991	30.22	49.77	46.59	53.44	10.99	34.02	83.43	61.97	35.46	110.47	0.00	0.00	516.36
1992	0.00	0.44	0.00	0.00	0.00	28.73	71.65	51.07	56.72	65.78	29.01	21.04	324.42
1993	80.14	68.76	90.80	53.16	0.00	4.23	37.37	18.62	50.34	68.94	17.88	13.14	503.39
1994	27.06	78.64	34.69	7.76	26.29	74.75	30.46	54.97	55.48	61.78	61.80	83.76	597.45
1995	136.49	29.46	38.64	9.54	0.00	2.74	24.64	68.27	62.24	89.69	107.62	-0.12	569.21
Total	1,214.80	981.69	797.24	937.73	275.71	631.06	916.91	1,110.72	1,192.02	1,604.92	1,875.65	716.95	12,255.40

50 to 99%   >100%

Table C-7. Monthly Runoff Coefficients for C-23 Basin Based on Observed Runoff Rainfall Ratio

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
1965	0.00	22.15	26.40	6.66	3.65	0.16	17.90	44.35	29.06	39.10	88.88	10.65	288.97
1966	49.27	56.93	23.53	5.46	8.19	20.03	141.61	54.51	26.54	53.77	19.27	3.14	462.26
1967	0.74	5.13	10.46	13.16	0.00	9.38	30.95	15.38	9.38	12.55	8.59	0.00	115.72
1968	0.00	0.00	0.00	0.00	9.94	45.66	79.22	32.48	6.49	20.78	21.58	0.00	216.15
1969	1.42	3.51	20.46	6.53	12.89	67.79	36.29	64.45	42.04	72.10	174.00	53.09	554.56
1970	55.36	26.77	22.49	3,661.52	4.09	14.91	75.86	80.33	22.35	38.78	45.69	0.00	4,048.15
1971	0.00	0.00	0.00	0.00	0.00	1.19	20.77	37.44	25.46	32.02	58.92	6.14	181.94
1972	1.03	5.02	6.28	25.51	13.09	53.94	9.33	23.36	5.00	0.51	0.03	0.00	143.10
1973	0.57	35.36	16.08	0.84	0.58	38.56	26.16	25.37	48.69	35.44	338.42	68.05	634.13
1974	0.00	0.00	0.00	0.00	0.13	9.34	30.29	75.71	61.26	24.89	0.00	0.36	201.98
1975	0.00	1.03	1.80	11.22	10.83	23.58	29.25	32.49	21.77	42.63	0.00	0.00	174.59
1976	0.00	0.00	0.00	0.00	31.83	54.20	12.32	18.40	18.04	0.00	2.99	18.53	156.31
1977	21.91	24.65	1.23	0.41	2.05	2.35	4.63	14.08	25.55	3.58	35.63	37.03	173.12
1978	45.81	34.71	42.32	11.30	2.98	13.27	15.38	26.56	24.35	24.82	30.18	8.16	279.84
1979	65.76	213.01	12.00	0.72	5.91	9.07	16.99	14.16	41.60	92.95	17.52	31.27	520.94
1980	9.02	36.02	10.85	11.46	0.56	1.77	9.31	20.21	47.77	2.95	11.30	8.71	169.92
1981	1.42	11.40	0.36	2.99	0.39	0.95	1.93	24.08	4.07	1.55	14.14	26.90	90.20
1982	2.89	15.16	23.79	28.34	19.40	37.00	36.83	42.42	40.65	34.96	18.30	16.23	315.97
1983	4.78	53.65	62.51	24.38	2.02	6.76	6.31	17.98	43.88	48.19	61.74	13.49	345.68
1984	104.50	16.50	26.47	18.37	9.13	13.19	18.15	25.27	26.56	86.82	37.56	109.10	491.61
1985	0.00	0.00	12.72	15.95	0.00	0.18	24.72	48.34	47.58	76.47	22.34	2.81	251.11
1986	29.86	10.88	10.53	0.00	6.25	36.54	44.20	53.86	59.18	23.58	21.20	19.40	315.48
1987	71.38	19.78	30.60	165.85	0.36	0.66	9.05	9.17	11.22	25.51	42.53	784.80	1,170.92
1988	18.21	28.77	16.07	1.95	2.35	-3.24	6.19	7.57	29.97	5.58	8.39	-20.37	101.44
1989	7.41	-44.51	0.00	0.00	0.00	0.00	0.49	23.12	-4.77	-4.25	0.00	-7.75	-30.27
1990	0.00	0.00	0.00	0.00	-8.32	11.61	8.47	5.97	4.51	11.71	36.66	3.55	74.17
1991	21.55	-9.07	55.25	29.76	57.66	32.33	28.63	66.36	76.62	39.96	0.00	7.31	406.36
1992	0.00	0.50	0.00	0.00	0.00	17.80	57.76	54.24	51.41	108.44	59.75	79.97	429.87
1993	58.62	59.90	62.66	67.28	5.96	14.11	23.32	17.90	32.31	-2.99	14.32	6.81	360.20
1994	21.76	48.69	28.67	26.93	42.78	57.77	36.23	34.26	50.45	45.83	51.03	41.83	486.22
1995	23.47	15.24	26.47	0.02	0.00	4.16	23.11	59.72	56.29	82.32	35.82	0.00	326.62
Total	616.71	691.16	549.99	4,136.59	244.71	595.01	881.66	1,069.54	985.30	1,080.59	1,276.79	1,329.22	13,457.27

Legend: missing (green); 50 to 99% (cyan); >100% (yellow)

Problem 3: ????

The hourly rainfall station data has many gaps. Also, the interior gages such as Cow Creek Ranch, Hayes Property, and Bluegoose tend to register lower rainfall amounts, an average of 12 to 17 inches per year lower, than the other stations. In 1998, an effort was made to verify data and fill the data gaps.

The soil parameter values were first evaluated based on the assumption of no irrigation withdrawals from local resources and no RCHRES option in place. This scenario is designated as Simulation 1. Under this scenario, if the monthly flow compared favorably with the observed monthly flow at the S-49 and S-97 structures, then the parameter values used in the model will be considered reasonable. The values in general are not much different from the values used by the Aqua Terra Consultants in their 1997 study except the upper and lower influence elevations were slightly reduced.

Figures C-3 and **C-4** present the comparison of observed and simulated monthly flows at S-97 under Simulation 1. In general, good agreement exists for wet season months. The agreement is not as good for dry season months. The simulated flow during the dry season tends to be higher than the observed flow. This is reasonable because the irrigation and RCHRES option were not applied. The farmers conserve water for their irrigation needs during dry months and water is withdrawn from the canal system. Therefore, less runoff is being released through the main water control structures such as S-49 and S-97.

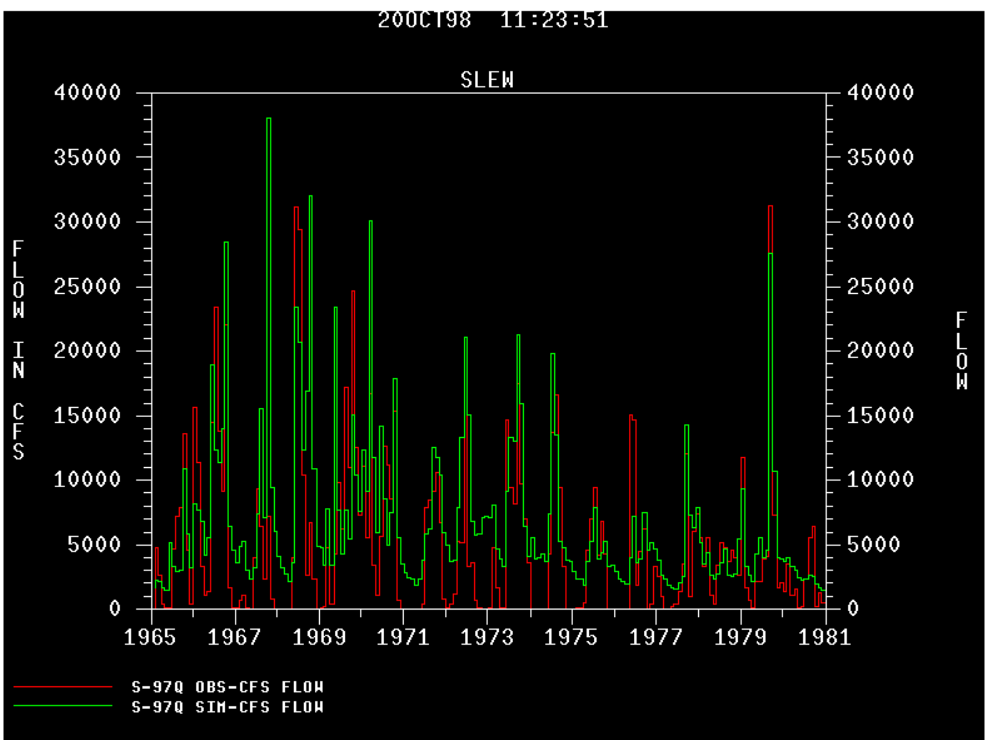

Figure C-3. Observed and Simulated Monthly Flow at S-97 without Irrigation Scheme for 1965 to 1980

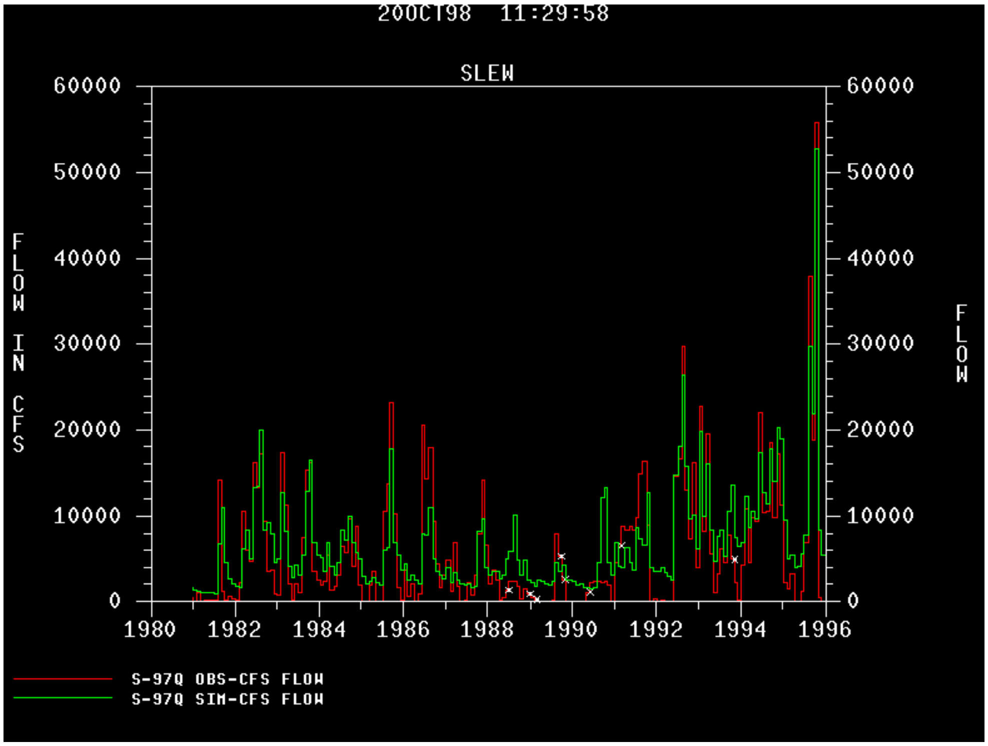

Figure C-4. Observed and Simulated Monthly Flow at S-97 without Irrigation Scheme for 1981 to 1995

Figures C-5 and **C-6** presents the comparison of observed and simulated monthly flows at S-97 under Scenario 2. Under this scenario, the supplemental irrigation and RCHRES option are included in the model simulation and the results are much better for both wet and dry seasons. The irrigation withdrawn from the C-24 Canal not only irrigates citrus within the C-24 Basin, it also irrigates the farms located within the North St. Lucie Water Control District. The amount of water and irrigated acreages are not available, so the estimation of total surface water irrigation for the C-24 Basin presented in the water budget at the end of this appendix may be too high.

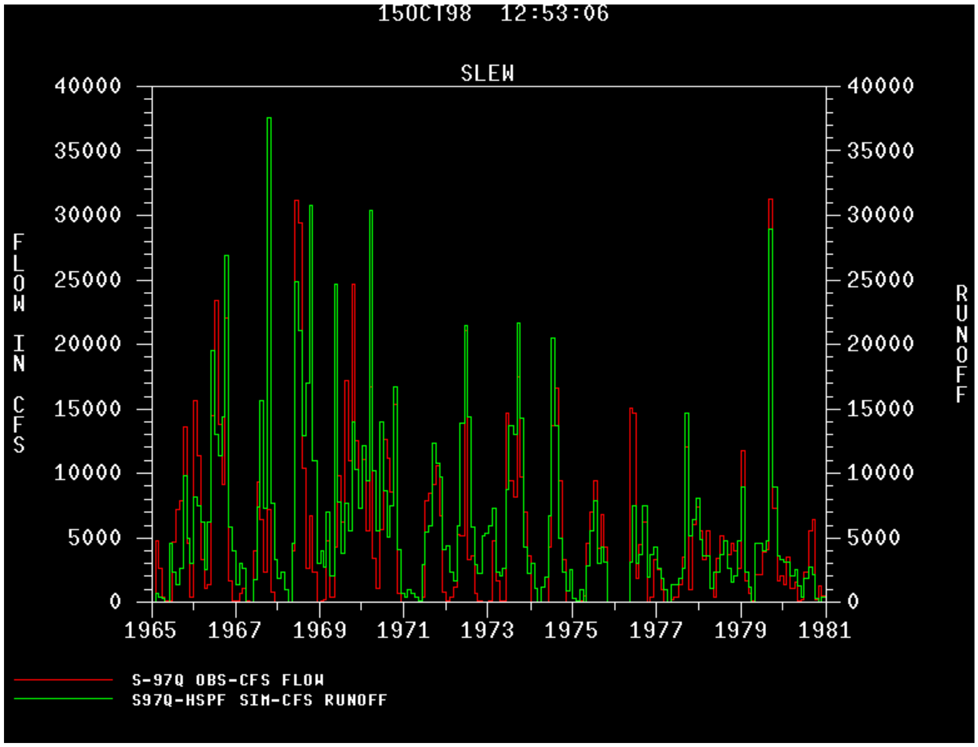

Figure C-5. Observed and Simulated Monthly Flow at S-97 with Irrigation Scheme for 1965 to 1980

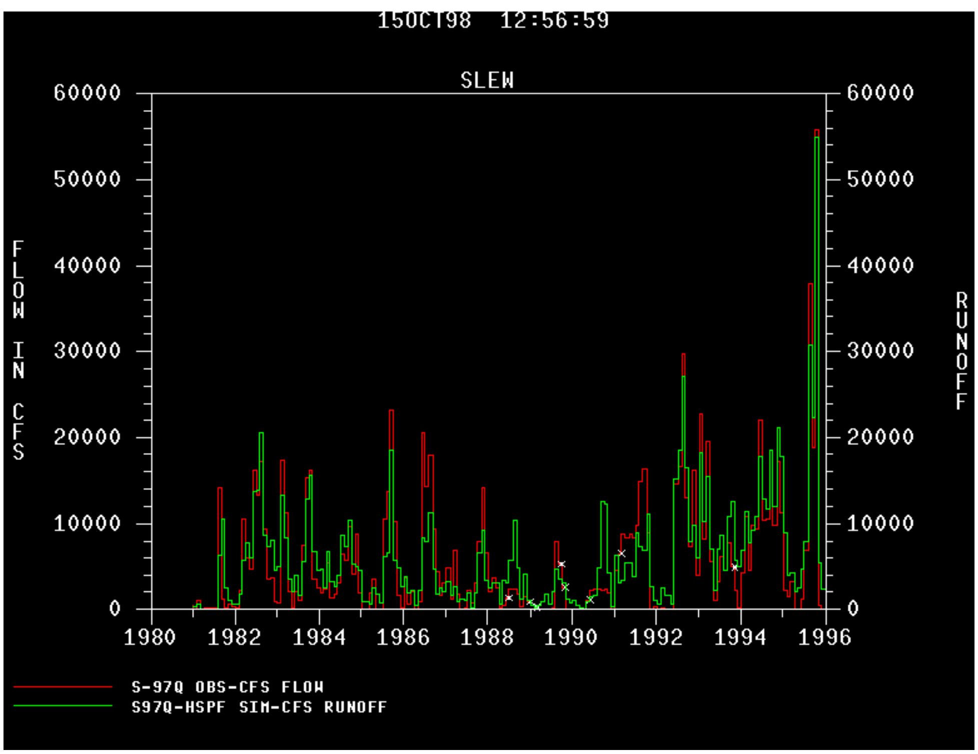

Figure C-6. Observed and Simulated Monthly Flow at S-97 with Irrigation Scheme for 1981 to 1995

Figures C-7 through **C-9** present the comparison of daily observed and simulated stage at S-97, which is an automatic gated structure. The gate opens and closes according to the incoming flow and water level upstream of the structure. The daily flow goes up and down rather quickly due to the gate rapidly opening and closing. The rapid widening and contracting of the flow pathway caused by the gate opening and closing cannot be simulated correctly by the model. In the model, the discharge releases were based on structure capacity limits, optimum stage, and the amount of incoming runoff. This may explain why the daily simulation tends to produce smaller flows than observed conditions.

Another difference between actual operation of the structure and the simulated operation of the structure is stage maintained within the canal. During simulations, a seasonal optimum stage was maintained in the project canal. For example, in the C-23 Canal, stage was maintained at 20.5 to 22.2 feet NGVD during the wet season (May 15 to October 15) and 22.2 to 23.2 feet NGVD during dry season (October 16 to May 14). However, this schedule was not followed exactly every year by the SFWMD's operation staff (**Figures C-7** through **C-9**).

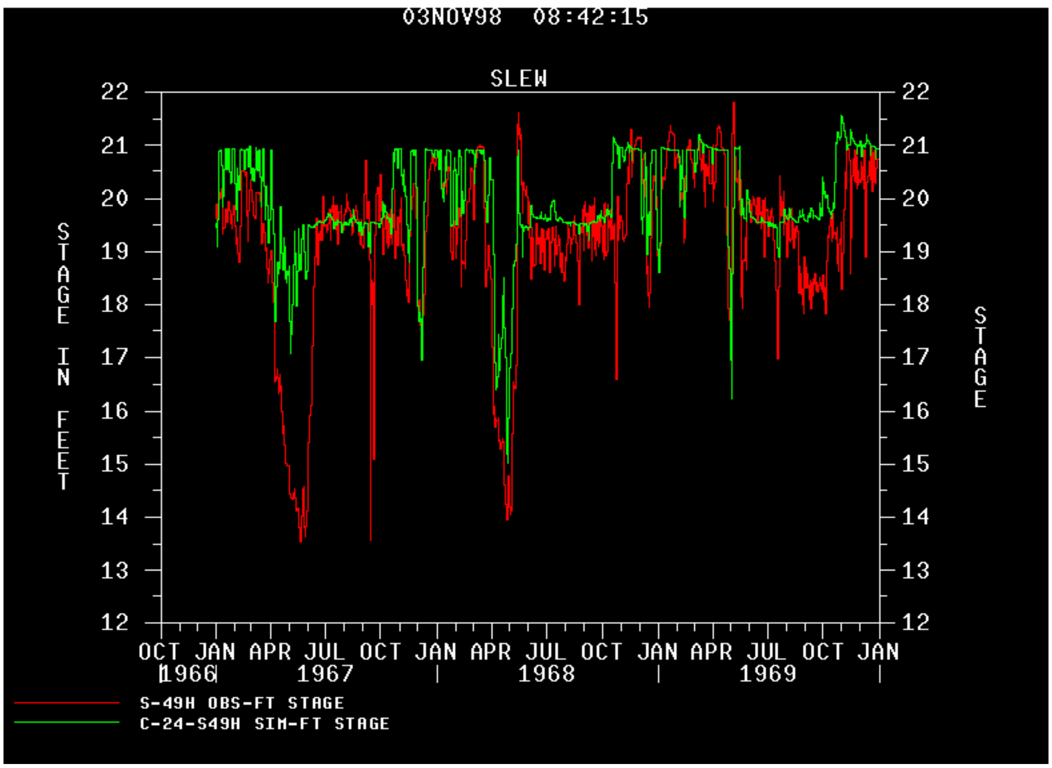

Figure C-7. Comparison of Observed and Simulated Daily Stage at S-49 for 1966 to 1969

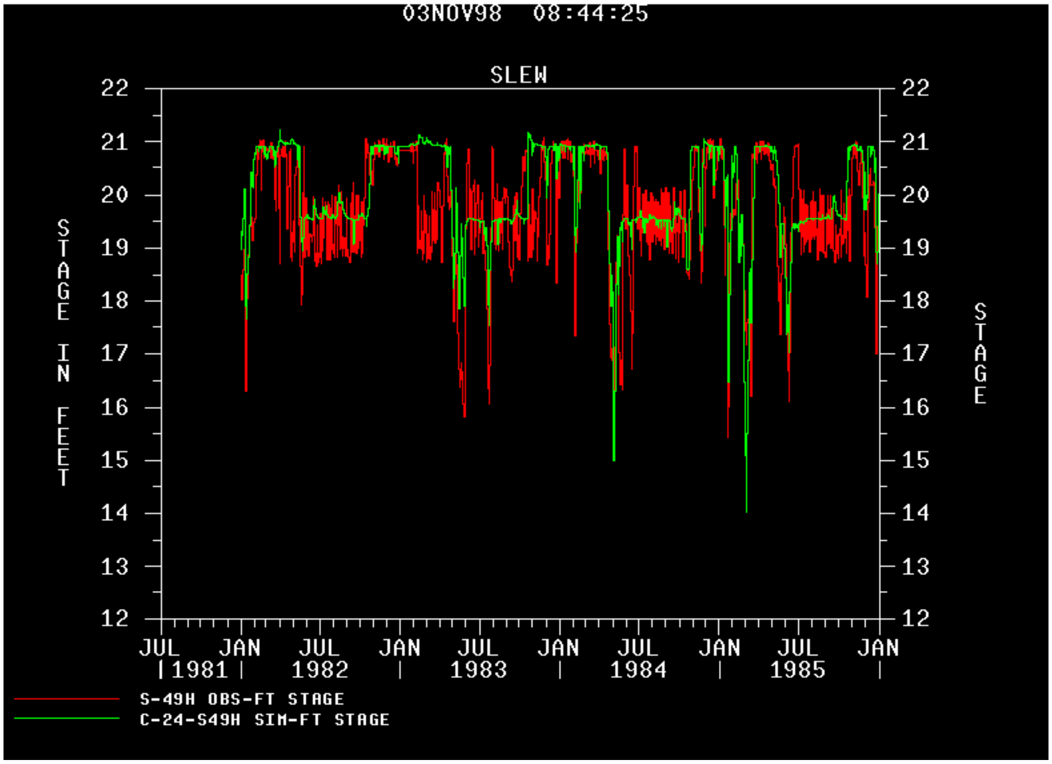

Figure C-8. Comparison of Observed and Simulated Daily Stage at S-49 for 1981 to 1985

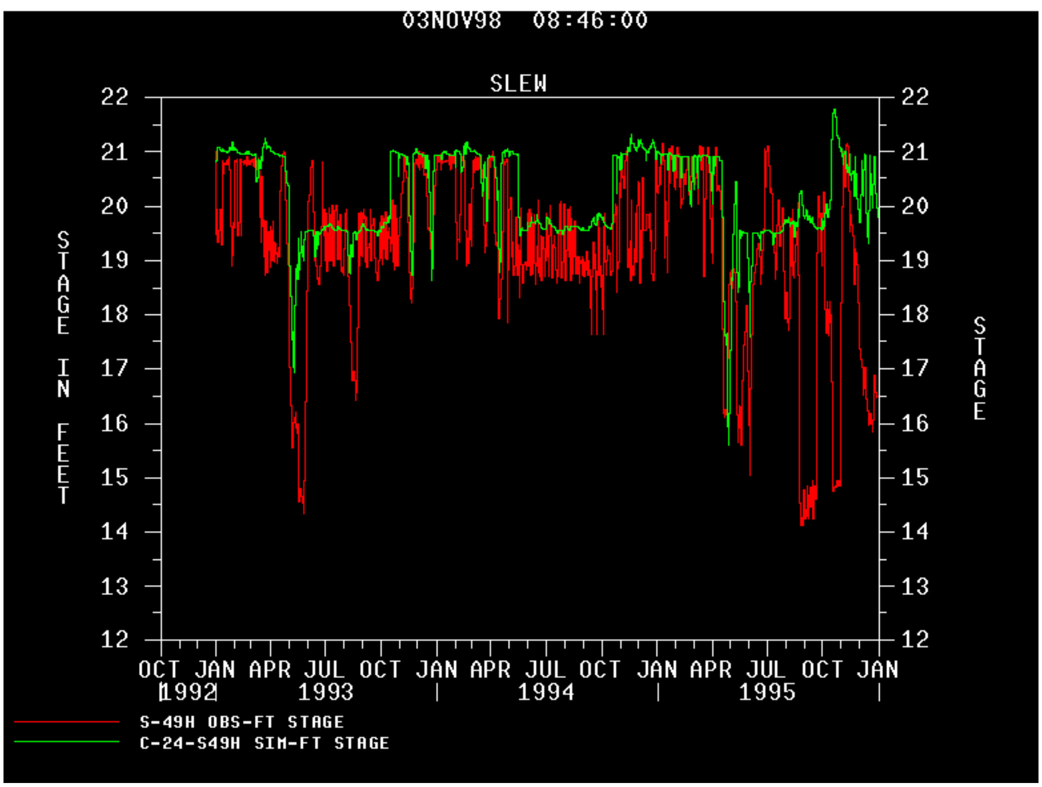

Figure C-9. Comparison of Observed and Simulated Stage at S-49 for 1992 to 1995

Figure C-10 presents a comparison of observed and simulated monthly flow frequency curves at S-97. Both curves are fairly close except for the low flow conditions. Noted that several months of observed data are missing.

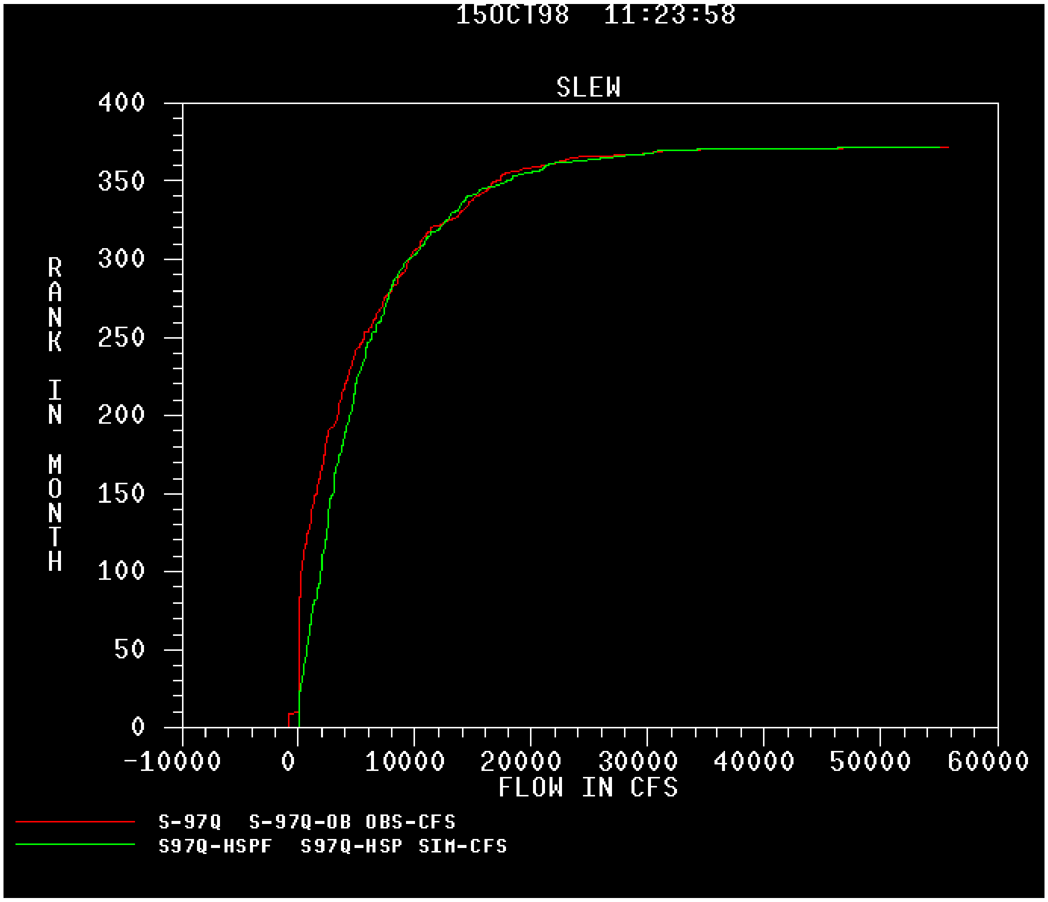

Figure C-10. Comparison of Observed and Simulated Monthly Flow Frequency Curves at S-97

Figure C-11 presents the comparison of observed and simulated average monthly flow from the C-23 Basin under Scenario 1 and Scenario 2. The simulated values tend to be slightly higher due to the assumption used for land uses. The land use of 1994 was used throughout the period from January 1965 through December 31, 199 even though developed area has increased substantially since 1965.

The simulation results may be improved further by better estimation of daily supplemental irrigation and ground water withdrawals based on seasonal demand. However, the this improvement would not be substantial enough to justify the additional efforts it would require.

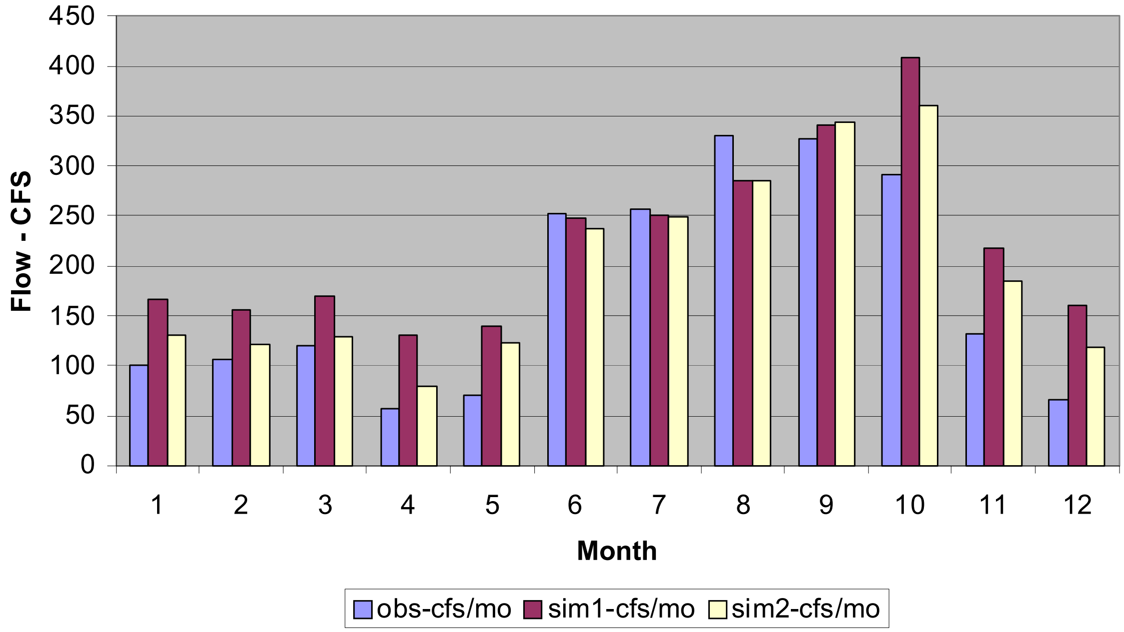

Figure C-11. Comparison of Observed and Simulated Average Monthly Flows from the C-23 Basin

Figures C-12 and **C-13** present comparisons of observed and simulated monthly flow at the S-49 structure located in the C-24 Basin under Scenario 2 for the period beginning January 1965 and ending December 1995. **Figure C-14** presents a comparison of observed and simulated average monthly flow for the C-24 Basin. **Figure C-15** presents a comparison of observed and simulated monthly flow frequency curves for S-49.

Figures C-16 through **C-18** present a comparison of observed and simulated daily flow and stage data at S-49. In general, the observed and simulated stage values are in agreement, but the daily flow has less agreement for the same reasons explained previously.

In **Table C-6**, 20 percent of the runoff rainfall ratios for the C-24 Basin that exceeded 50 percent are considered questionable. WHAT IS THE PURPOSE OF THIS STATEMENT HERE? NEED MORE ELABORATION.

Overall, the results indicate that the parameter values used in the C-23 and C-24 Basins can be applied to the rest of the St. Lucie Estuary watershed for model calibrations and applications when no observed data is available.

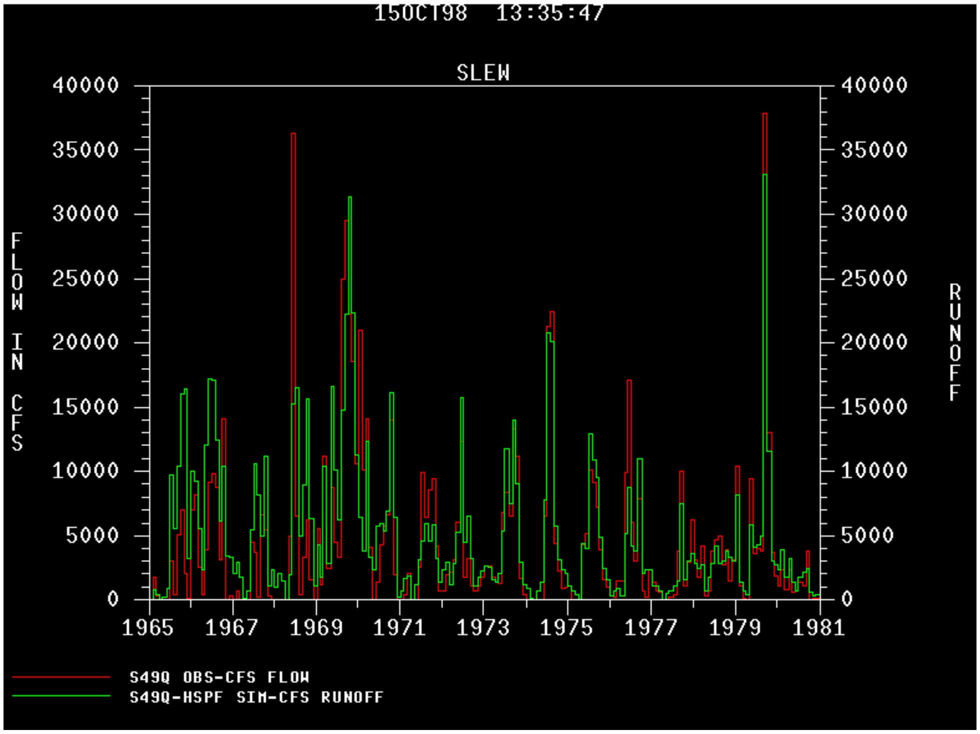

Figure C-12. Observed and Simulated Monthly Flow with Irrigation Scheme from 1965 to 1980

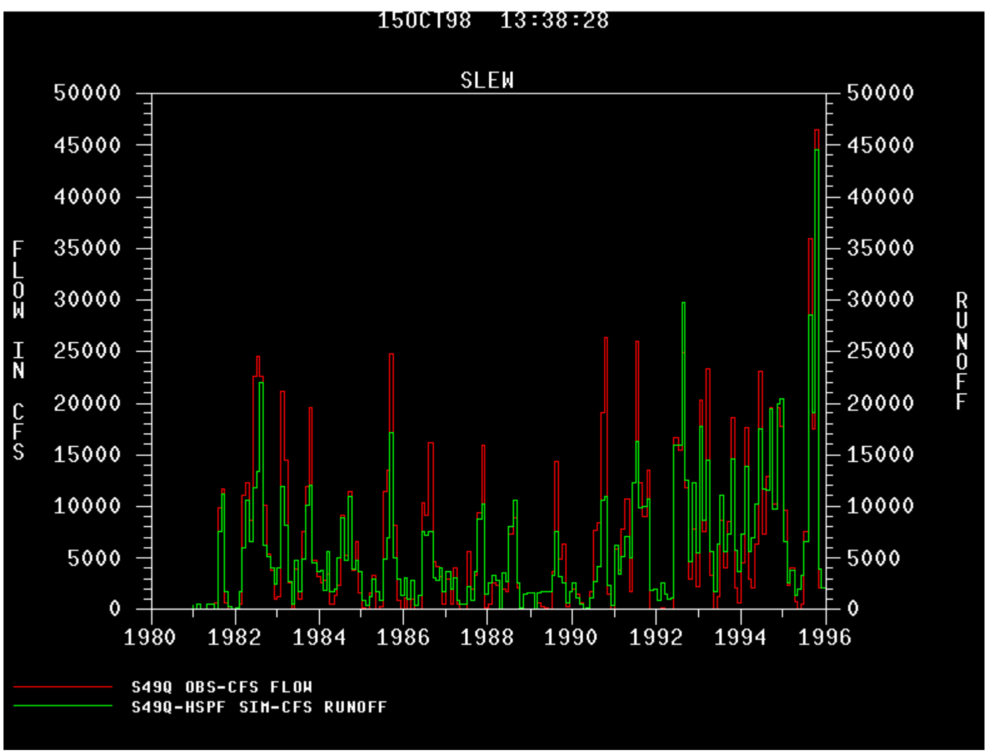

Figure C-13. Observed and Simulated Monthly Flow with Irrigation Scheme from 1981 to 1995

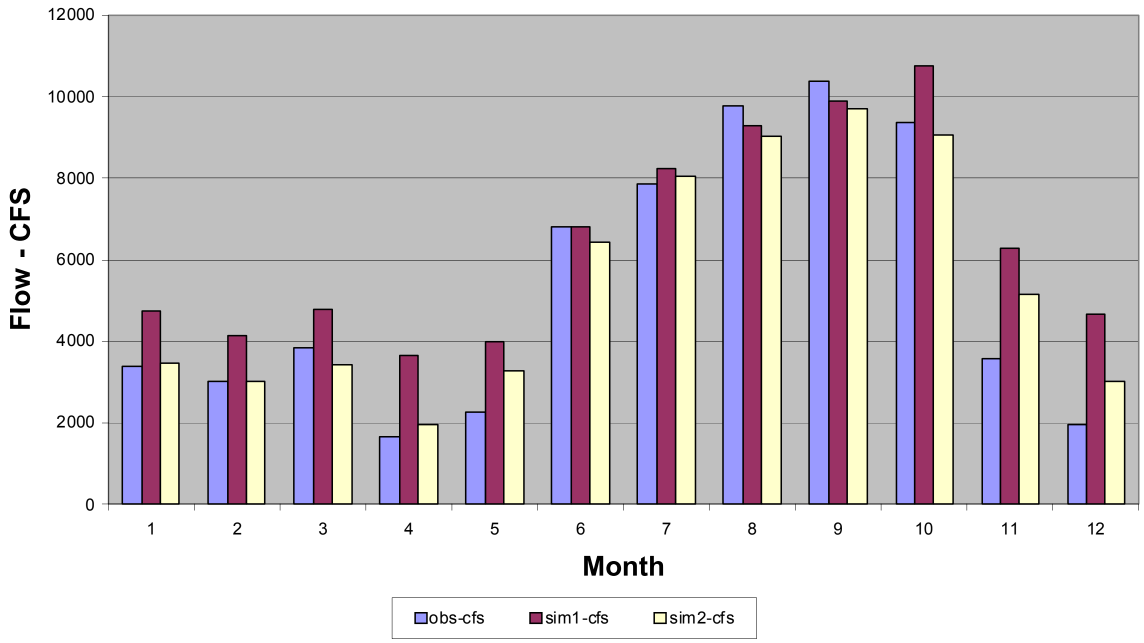

Figure C-14. Comparison of Observed and Simulated Averaged Monthly Flows from C-24 Basin

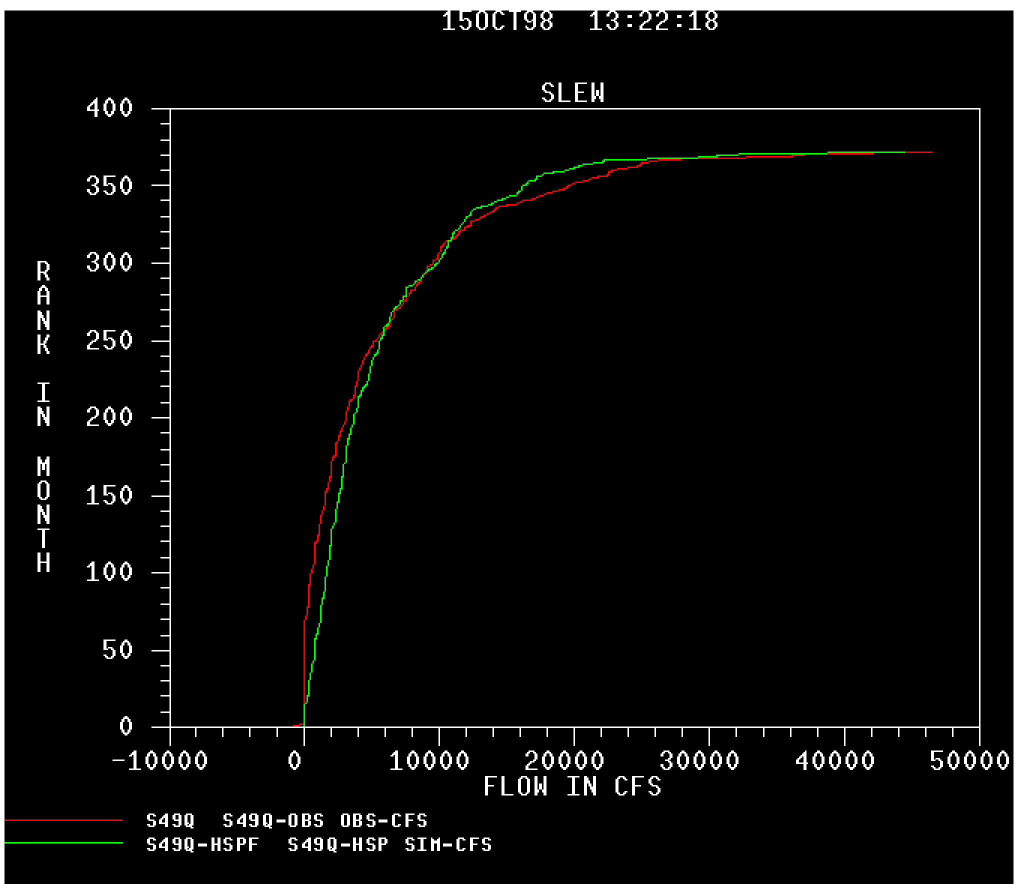

Figure C-15. Comparison of Observed and Simulated Monthly Frequency Curves at S-49

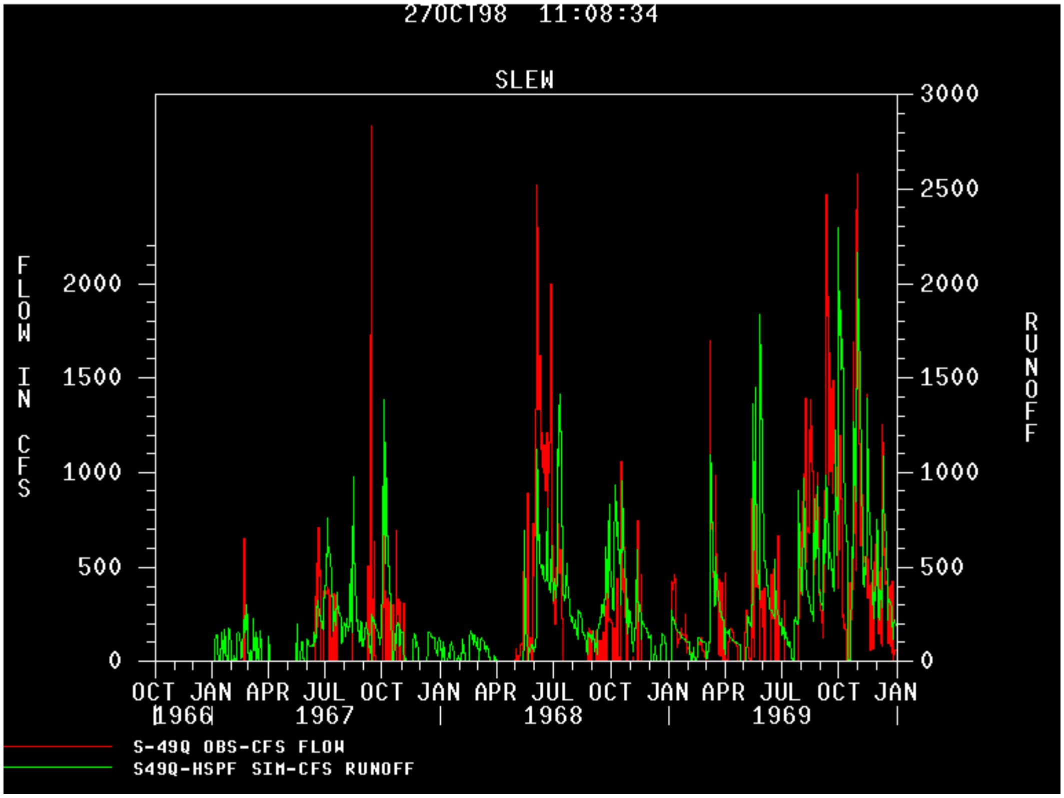

Figure C-16. Comparison of Observed and Simulated Daily Flow at S-49 from 1966 to 1969

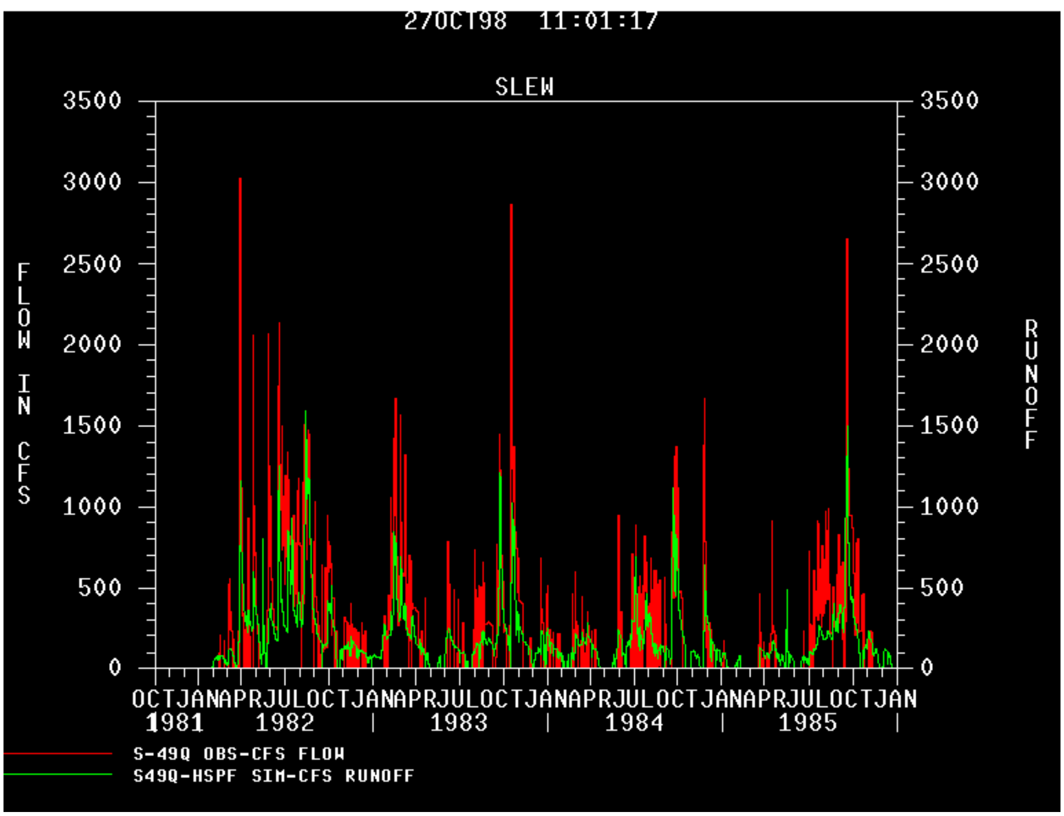

Figure C-17. Comparison of Observed and Simulated Daily Flow at S-49 from 1981 to 1985

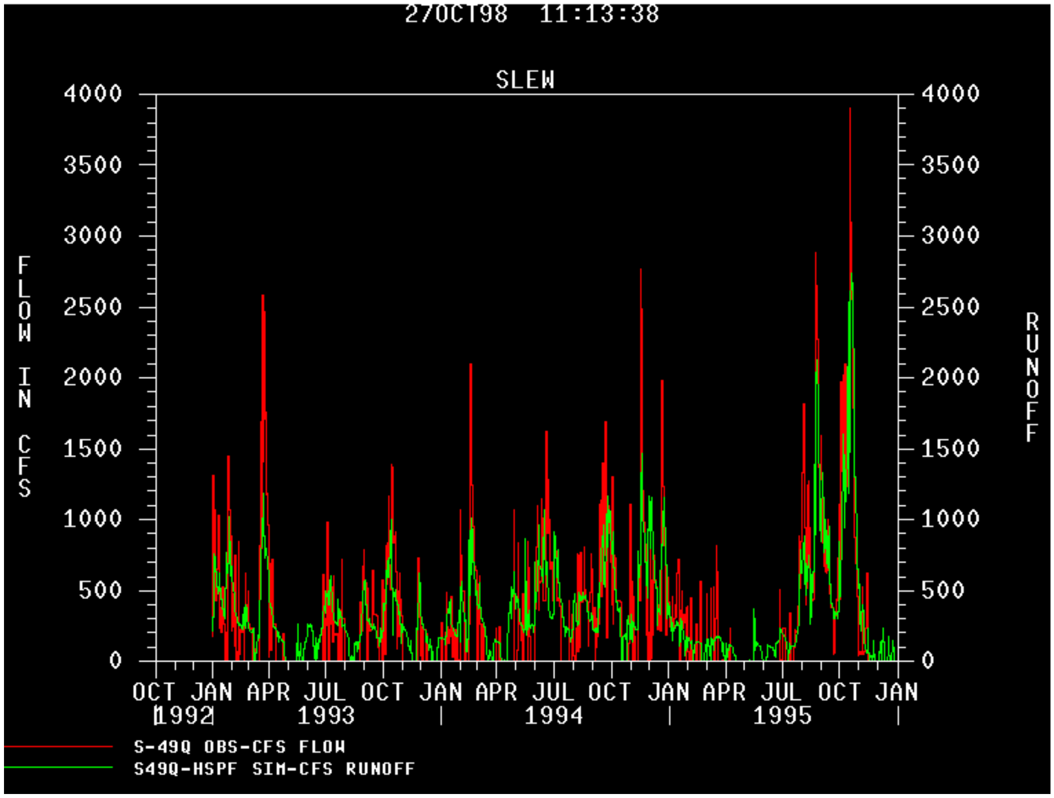

Figure C-18. Comparison of Observed and Simulated Daily Flow at S-49 from 1992 to 1995

WATER BUDGET FOR ST. LUCIE ESTUARY WATERSHED

Table C-8 presents the completed water budget for the watershed based on the HSPF modeling analysis. Water budgets for each basin within the watershed are provided in **Tables C-9** through **C-16**. The HSPF model has a built-in water budget balance check at each time step. The slight unbalance shown in the table was primarily caused by truncation and runoff error within the spread sheet.

Table C-8. Water Budget for the St. Lucie Watershed

Parameter	Actual Values (inches per year)	Water Budget Calculations: inches per year	Water Budget Calculations: acre-feet per year
Rainfall	52.17	52.17	2,169,613
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	35.31	-35.31	-1,468,361
Irrigation			
From stream (71%)	2.48		
From Floridan Aquifer[a] and Lake Okeechobee (29%)	1.44	1.44	59,945
Land Use Runoff	20.67		
Basin Runoff	18.32	-18.32	-761,883
Balance		-0.02	-686

Actual Evapotranspiration for Each Land Use[b]

Land Use	inches per year	acres	acre-feet per year
Forest	36.43	40,358	122,521
Groves	39.50	140,331	461,926
Pasture	34.51	141,140	405,913
Urban Impervious	10.17	29,982	25,413
Urban Pervious	34.88	44,951	130,663
Wetland	37.77	102,271	321,924
Basin Total	35.31	499,034	1,468,361

Runoff from Each Land Use[b]

Land Use	inches per year	acres	acre-feet per year
Forest	15.84	40,358	53,278
Groves	26.39	140,331	308,653
Pasture	16.91	141,140	198,851
Urban Impervious	18.12	44,951	67,862
Urban Pervious	43.06	29,982	107,598
Wetland	14.49	102,271	123,528
Basin Total	20.67	499,034	859,770

Irrigation

Source	inches per year for groves	acres	acre-feet per year	inches per year for basin
Stream	8.81	140,331	102,989	2.48
Floridan Aquifer and Lake Okeechobee	5.13	140,331	59,945	1.44
Total	13.93	140,331	162,934	3.92

a. Irrigation from the Floridan Aquifer is considered an external source

b. Approximate values

Table C-9. Water Budget for the C-23 Basin

Parameter	Actual Values (inches per year)	Water Budget Calculations	
		inches per year	acre-feet per year
Rainfall	50.70	50.70	473,298
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	36.64	-36.64	-342,002
Irrigation			
From stream (71%)	2.32		
From Floridan Aquifer[a] and Lake Okeechobee (29%)	0.93	.093	8,655
Land Use Runoff	17.33		
HSPF Basin Runoff	15.28	-15.28	-142,643
Observed Basin Runoff	13.88		
Balance		-0.29	-2,692

Actual Evapotranspiration for Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	36.66	5,387	16,455
Groves	39.15	34,596	112,860
Pasture	34.85	47,128	136,876
Urban Impervious	13.42	1,273	1,423
Urban Pervious	34.85	1,887	5,480
Wetland	38.03	21,743	68,907
Basin Total	36.64	112,013	342,002

Runoff from Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	13.79	5,387	6,190
Groves	21.74	34,596	62,668
Pasture	15.61	47,128	61,302
Urban Impervious	37.29	1,273	3,954
Urban Pervious	15.61	1,887	2,454
Wetland	12.72	21,743	23,039
Basin Total	17.33	112,013	159,607

Irrigation				
Source	**inches per year for groves**	**acres**	**acre-feet per year**	**inches per year for basin**
Stream	7.51	34,596	21,638	2.32
Floridan Aquifer and Lake Okeechobee	3.00	34,596	8,655	0.93
Total	10.51	34,596	30,293	3.25

a. Irrigation from the Floridan Aquifer is considered an external source

b. Approximate values

Table C-10. Water Budget for the C-24 Basin

Parameter	Actual Values (inches per year)	Water Budget Calculations: inches per year	Water Budget Calculations: acre-feet per year
Rainfall	50.95	50.95	386,305
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	35.03	-35.03	-265,643
Irrigation			
From stream (71%)	3.20		
From Floridan Aquifer[a] and Lake Okeechobee (29%)	1.28	1.28	9,697
Land Use Runoff	20.23		
HSPF Basin Runoff	17.16	-17.16	-130,092
Observed Basin Runoff	16.70		
Balance		0.04	267

Actual Evapotranspiration for Each Land Use[b]

Land Use	inches per year	acres	acre-feet per year
Forest	35.26	6,968	20,472
Groves	37.85	20,646	65,115
Pasture	33.70	41,827	117,476
Urban Impervious	13.52	1,184	1,333
Urban Pervious	33.70	1,775	4,986
Wetland	36.32	18,589	56,260
Basin Total	35.03	90,988	265,643

Runoff from Each Land Use[b]

Land Use	inches per year	acres	acre-feet per year
Forest	15.42	6,968	8,952
Groves		20,646	
Pasture	16.98	41,827	59,198
Urban Impervious	37.43	1,184	3,692
Urban Pervious	16.98	1,775	2,513
Wetland	14.65	18,589	22,691
Basin Total	20.23	90,988	153,401

Irrigation

Source	inches per year for groves	acres	acre-feet per year	inches per year for basin
Stream	14.09	20,646	24,242	3.20
Floridan Aquifer and Lake Okeechobee	5.64	20,646	9,697	1.28
Total	19.74	20,646	33,939	4.48

a. Irrigation from the Floridan Aquifer is considered an external source

b. Approximate values

Table C-11. Water Budget for Basins 4, 5, and 6

Parameter	Actual Values (inches per year)	Water Budget Calculations	
		inches per year	acre-feet per year
Rainfall	53.91	53.91	66,268
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	31.62	-31.62	-38,865
Irrigation	0.00		
Land Use Runoff	22.11		
HSPF Basin Runoff	22.12	-22.12	-27,181
Observed Basin Runoff	NA[a]		
Balance		0.17	222
Actual Evapotranspiration for Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	36.29	3,491	10,559
Groves	34.74	420	1,217
Pasture	34.59	2,530	7,293
Urban Impervious	12.24	2,510	2,561
Urban Pervious	34.59	3,766	10,855
Wetland	37.67	2,033	6,381
Basin Total	31.67	14,750	38,865
Runoff from Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	17.34	3,491	5,046
Groves	18.96	420	664
Pasture	19.06	2,530	4,018
Urban Impervious	41.68	2,510	8,719
Urban Pervious	19.06	3,766	5,981
Wetland	16.26	2,033	2,753
Basin Total	22.11	14,750	27,181
Irrigation			
Irrigation for groves is assumed to be insignificant.			

a. NA = Not available
b. Approximate values

Table C-12. HSPF Water Budget for the S-153 Basin

Parameter	Actual Values (inches per year)	Water Budget Calculations	
		inches per year	acre-feet per year
Rainfall	47.41	47.41	51,045
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	33.59	-33.59	-36,167
Irrigation	0.00		
Land Use Runoff	13.70		
HSPF Basin Runoff	13.70	-13.70	-14,746
Observed Basin Runoff	NA[a]		
Balance		0.12	132
Actual Evapotranspiration for Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	34.65	1,428	4,124
Groves	32.88	2,069	5,670
Pasture	32.68	4,129	11,244
Urban Impervious	8.47	447	316
Urban Pervious	32.68	671	1,828
Wetland	37.32	4,175	12,985
Basin Total	33.59	12,920	36,167
Runoff from Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	12.49	1,428	1,486
Groves	14.42	2,069	2,486
Pasture	14.47	4,129	4,977
Urban Impervious	38.95	447	1,452
Urban Pervious	14.47	671	809
Wetland	10.16	4,175	3,534
Basin Total	13.70	12,920	14,746
Irrigation			
Irrigation for groves is assumed to be insignificant.			

a. NA = Not available
b. Approximate values

Table C-13. HSPF Water Budget for the South Fork Basin

Parameter	Actual Values (inches per year)	Water Budget Calculations	
		inches per year	acre-feet per year
Rainfall	53.71	53.71	212,775
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	33.31	-33.31	-131,941
Irrigation	0.00		
Land Use Runoff	20.23		
HSPF Basin Runoff	20.23	-20.23	-80,145
Observed Basin Runoff	NA[a]		
Balance		0.17	689
Actual Evapotranspiration for Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	35.87	4,548	13,592
Groves	34.06	6,409	18,193
Pasture	34.16	14,706	41,860
Urban Impervious	12.39	3,928	4,055
Urban Pervious	34.16	5,892	16,722
Wetland	37.30	12,053	37,468
Basin Total	33.31	47,537	131,941
Runoff from Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	17.56	4,548	6,654
Groves	19.44	6,409	10,385
Pasture	19.28	14,706	23,626
Urban Impervious	41.33	3,928	13,530
Urban Pervious	19.28	5,892	9,467
Wetland	16.41	12,053	16,484
Basin Total	20.23	47,537	80,145
Irrigation			
Irrigation for groves is assumed to be insignificant.			

a. NA = Not available

b. Approximate values

Table C-14. HSPF Water Budget for the C-44 Basin

Parameter	Actual Values (inches per year)	Water Budget Calculations	
		inches per year	acre-feet per year
Rainfall	53.26	53.26	515,258
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	38.32	-38.32	-370,744
Irrigation			
From stream (71%)	2.96		
From Floridan Aquifer[a] and Lake Okeechobee (29%)	3.12	3.12	30,191
Land Use Runoff	21.03		
HSPF Basin Runoff	17.91	-17.91	-173,293
Observed Basin Runoff	NA[b]		
Balance		0.14	1,383

Actual Evapotranspiration for Each Land Use[c]

Land Use	inches per year	acres	acre-feet per year
Forest	37.28	7,490	23,265
Groves	40.77	48,873	166,049
Pasture	35.57	25,372	75,212
Urban Impervious	13.91	1,724	1,999
Urban Pervious	35.57	2,587	7,668
Wetland	38.57	30,049	96,581
Basin Total	38.32	116,095	370,774

Runoff from Each Land Use[b]

Land Use	inches per year	acres	acre-feet per year
Forest	16.02	7,490	10,000
Groves	26.63	48,873	108,469
Pasture	17.74	25,372	37,508
Urban Impervious	39.67	1,724	5,700
Urban Pervious	17.74	2,587	3,824
Wetland	15.00	30,049	37,568
Basin Total	21.03	116,095	203,069

Irrigation

Source	inches per year for groves	acres	acre-feet per year	inches per year for basin
Stream	7.02	48,873	28,604	2.96
Floridan Aquifer and Lake Okeechobee	7.41	48,873	30,191	3.12
Total	14.45	48,873	58,795	6.08

a. Irrigation from the Floridan Aquifer is considered an external source
b. NA = Not available
c. Approximate values

Table C-15. HSPS Water Budget for the North Fork Basin

Parameter	Actual Values (inches per year)	Water Budget Calculations	
		inches per year	acre-feet per year
Rainfall	53.24	53.24	464,665
Potential Evapotranspiration	64.00		
Actual Evapotranspiration	32.42	-32.42	-282.970
Irrigation From stream (71%) From Floridan Aquifer[a] and Lake Okeechobee (29%)	 3.27 1.31	 1.31	 11,402
Land Use Runoff	25.47		
HSPF Basin Runoff	22.20	-22.20	-193.777
Observed Basin Runoff	NA[b]		
Balance		-0.08	-680

Actual Evapotranspiration for Each Land Use[c]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	36.99	11,047	34,054
Groves	40.78	27,317	92,821
Pasture	35.13	5,448	15,953
Urban Impervious	8.71	18,916	13,074
Urban Pervious	35.13	28,373	83,074
Wetland	38.16	13,630	43,341
Basin Total	32.42	104,731	282,970

Runoff from Each Land Use[b]			
Land Use	**inches per year**	**acres**	**acre-feet per year**
Forest	16.24	11,047	14,949
Groves	29.71	27,317	67,625
Pasture	18.11	5,448	8,222
Urban Impervious	44.76	18,916	70,552
Urban Pervious	18.11	28,373	42,815
Wetland	15.37	13,630	17,458
Basin Total	25.47	104,731	221,621

Irrigation				
Source	**inches per year for groves**	**acres**	**acre-feet per year**	**inches per year for basin**
Stream	12.52	27,317	28,505	3.27
Floridan Aquifer and Lake Okeechobee	5.01	27,317	11,402	1.31
Total	17.53	27,317	39,907	4.57

a. Irrigation from the Floridan Aquifer is considered an external source
b. NA = Not available
c. Approximate values

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